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a perfect match

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TURN YOUR PC INTO AN OSCILLOSCOPE
we'll show you how

NO MORE ELECTRIC BILL
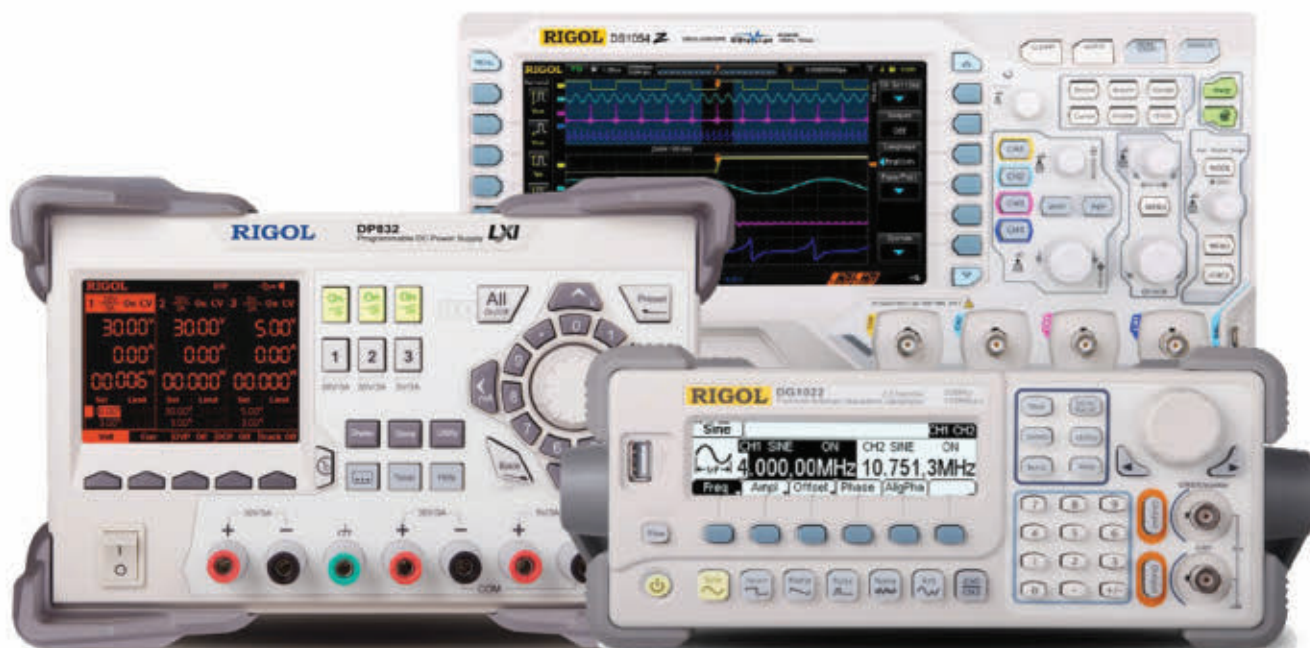a solar power saga

ADD VIRTUAL INSTRUMENTS
to your workbench

August 2016

Page 22

Departments

DEVELOPING PERSPECTIVES

by
Bryan Bergeron, Editor

Make History: Keep a Logbook

As a short wave listener and later as a ham radio operator, I kept a logbook of station frequency, signal strength, time of day, antenna, and other equipment specifics. With time, several patterns emerged such as the best time of day or best time of year to hear or contact stations in specific countries. Depending on the frequency, I could also see the gradual effect of the 11 year sunspot cycle on reception that was influenced by the state of the ionosphere.

Unfortunately, I wasn't as fastidious with my project work. I still have a few notebooks from early tube-type work, but then there's a decade or so gap when I was experimenting with transistors. The record picked up again with ICs and microcontrollers.

Now, of course, I wish I had taken notes and sketched out those discrete component circuits; in part because I can't remember the details, such as how many turns of what gauge wire to use to create an RF choke in a particular MOSFET amplifier circuit in a 1970-era transmitter.

Sure, there are pockets of information on the Web about the care and maintenance of vintage electronics, but it's not the same as my notes on my experiences.

My preferred method of taking notes is old-fashioned pencil and paper. Sure, I have iPads and notebook computers with cameras and voice recognition software, but it's just faster for me to jot down a circuit and a few notes in a notebook.

I have made it a practice to photograph circuits and projects in various stages of completion. Sometimes a photo is really worth at least a paragraph, but the core of my record taking is on paper.

Long-term archiving of my notes is another matter. To capture my thoughts, I use spiral notebooks with three-ring binder holes and tear-out perforations. When a notebook is filled, I carefully tear out each page and feed the pages into my Fuji ScanSnap page scanner ($410, Amazon) which does double-sided scans nicely.

I put the resulting PDF in a folder on my hard drive. At the end of the month, the PDF becomes part of a DVD-based archive — and sometimes to a Flash drive as well, for good measure. The paper goes into a three-ring binder, which I keep above my desk.

I'd like to think that my paper notes will outlast any electronic record, and it will always be available — even when the grid goes down. However, I'm probably kidding myself. If there's a war or natural disaster that takes out the power for weeks or months, I'm not going to be thinking about electronics — except perhaps how to maintain an electric generator.

My point in all of this is that you should at least consider maintaining a record of your electronics adventures. It can be as simple as taking photos of your projects with your cell phone. You can also get in the habit of sketching out your circuits and writing down the process you used to get there.

So, go ahead, make history. **NV**

READER FEEDBACK

Terminology Troubles

I have been a subscriber to *Nuts & Volts* for over 20 years and to *SERVO Magazine* from its inception issue. Even with online availability, I still look forward to their arrival in the mail every month.

As a routine reader of Bryan Bergeron's column, I find that it generally expresses great salient arguments or perspectives that I tend to agree with or relate to.

On the column in the July 2016 issue, however, I perhaps choked a bit when reading the line "I have to admit a bias toward low level electron physics, simply because that's how I was exposed to electronics — the flow of electrons or positrons across barriers and through various crystalline lattices."

I'm sure you will agree that the use of correct terminology is important — particularly in any current technological or scientific field. Consequences of incorrect use could have deleterious or even catastrophic consequences. I am intrigued as to your understanding in this universe of "flow of ... positrons across barriers." Perhaps you may have been considering their behavior in some as yet undiscovered anti-universe. Although in such an anti-universe those "positronic" devices (please forgive me, Asimov) would likely function perfectly well. In our universe, however, things would be rather different. As far as my understanding would lead me to believe, any significant numbers of positrons crossing any barrier or lattice or just plain hanging around in this universe would likely do more than just let the magic smoke out of said device, but would look more like a scaled down mushroom cloud of sorts.

Outside the humorous giggle that I had when reading your passage, I was also able to commiserate with you in perhaps my normal and frequent frustration in sometimes trying to remember some arcane bit of jargon terminology that at my age just happened to not be available when needed in the neural network it resided in, and that has by now suffered some degree of non-functionality due to the inexorable toll of decades from just make-do inadequate repairs, free radical attrition, just plain loss of biological signal-to-noise ratio, and who knows what other kinds of failure modes. Perhaps just this is what befelled you when trying to describe electrons and holes. Yes, holes crossing barriers and lattices. I was never comfortable with the terminology of holes to represent positive charges in semiconductors. It seems so inelegant, so non-technical, and yet we are stuck with it in the atomic description of semiconductors in this universe.

Perhaps the anti-universe has discovered a more deserving term for those pesky negative charges moving around in their devices that is better than anti-positron bumps.

Adrian Clausell
San Diego, CA

I appreciate both the feedback and the fact that you've been a subscriber since day one. Point well taken! Yes, the old neural network may have coughed and choked on that one. It's been 40+ years since I sat in Circuits 101 in college, and had to change my thinking from electron flow to hole flow or movement.

Bryan Bergeron

Encounter of an HV Kind

I enjoyed reading "Getting Down to Earth" in the June issue.

For 38 years, I was an engineer; for the last 12 as chief engineer for WLEX-TV, a UHF station in the (before DTV) all-UHF Lexington, KY market. I'm reminded of a near-death experience I had many years ago.

The 60 KW RCA transmitter used two klystrons for visual amplifiers and one for aural. Since the collectors (plates) were water cooled, the cathodes were elevated to a negative 18.6 KV, including their six volt filament supplies. I'd been having occasional problems with the filament contacts on Visual #2.

At sign-on one morning, that tube failed to come on, so I made the drive to check it.

I removed the panel that covered the contacts, which had NO safety interlock like newer transmitters do. I pressed "XMTR On" which is only later followed by pressing "HV On" after warm-up. (I needed the filaments on to tell when the contact was made.)

My error was that I assumed the engineer had hit "HV Off" first to shut it down when, in fact, he had just hit "XMTR Off." Both modes had relays that latched into position, and there was no indication that the HV was in position to come on after the warm-up delay of a few minutes.

I first used the safety grounding cable and touched it to both filament/cathode contacts. Then when I confirmed no power on the tube, I used a screwdriver in my left hand to push on the contacts. Unfortunately, the warm-up delay timed out and the HV came on!

My Timex watch had a metal band (true, you shouldn't wear a watch around HV). In thinking about the sensation, it was like my whole hand was in a sealed water cylinder and someone slammed a sledge hammer on the piston. I felt extreme pressure! In a fraction of a second, the HV overload solenoid relay shut it down. The two visual tubes normally drew 10 amps and the overload was set to 12, so for several milliseconds I took over two amps at 18,600 volts through my middle finger, hand, and wrist — something over 37,000 watts!

I was thrown back, but got up and did what was needed to get the transmitter back on the air. I couldn't move my left wrist and one finger wouldn't bend. In 15 minutes, they worked just fine.

I went on home and slept awhile. Three people had been watching when the incident happened, so when I returned to the station I got a lot of attention. My GM had me

drive to a hospital to be checked.

The doctor said DC burns are very dangerous and that I could still lose the hand.

I wore that watch for years after, and showed people how the ridge on that side was rounded by the arc to the watch. Had I not been wearing

the watch, the arc would have been to my bare wrist and I would surely have lost the hand. I still have the screwdriver, which shows a slight puddle on the side of the blade.

The only mark was a spot on my

Quadcopters to the (Near Space) Rescue

There are times I wished I were sitting on an aerial perch. This is especially true after a near spacecraft lands long before the chase crew has a chance to arrive on the scene. Depending on the terrain and roads, chase crews might spend an hour driving around the landing zone before receiving a current position report from the near spacecraft. Having access to a portable radio tower that quickly assembles would shorten up this part of recovery immensely as you'll see in this article. That's where a quadcopter would come in handy.

The Blade Chroma has the horsepower to carry a payload weighing at least 13 ounces. This makes it ideal for mini-scale rescue missions for near spacecraft.

Radio Tracking Near Space Assets

Near space missions use a system of amateur radio tracking called the Automatic Packet Reporting System, or APRS. APRS converts the position of the GPS receiver into a series of tones, and then transmits that information over amateur radio. Chase crews receive and decode these signals, giving them the ability to keep up and eventually recover near spacecraft.

Some ground stations — called IGates — can receive the position reports of near space assets and forward the reports to the Internet. This enables chase crews to follow the near spacecraft using a combination of direct reception from the near spacecraft and Internet-connected devices.

These two methods are complementary, as sometimes chase crews are not in a position to receive direct transmissions from the near spacecraft but are in a position to get reception on their smartphones or vice versa.

Where this complementary system of tracking can fail is near landing. Depending on the position of the landing site, the position of the chase crews, and the location of IGates, there may be zero radio reception as the near spacecraft gets close to the ground. In some past missions, chase crews lost tracking of the near spacecraft over 1,000 feet above the ground.

This isn't necessarily a problem since chase crews can often receive a signal from the landed near spacecraft as they approach its last know position.

In some cases, however, the near spacecraft landed in a location where chase crews couldn't pick up radio signals as they drove around. In those cases, we resorted to walking through the recovery zone while looking for a brightly colored parachute or hoping for lucky radio reception.

How much better would it be if we could look down on the landing zone from an altitude of 100 feet? According to calculations, the horizon is just over 12 miles away at an altitude of 100 feet. Ideally then, chase crews wouldn't have to know the actual location where the near spacecraft landed in order to locate it. We would just need to monitor the recovery zone for a minute or two until the near spacecraft transmitted a position report the radio and antenna heard.

Realistically, it's just not practical to carry a 100 foot tall radio tower on a near space chase. The alternative is to attach a radio and antenna to a quadcopter and let the quadcopter hover at an altitude of 100 feet.

Getting a Radio

To put this into action, I first needed a radio. It had to be a radio capable of both receiving and transmitting a digital radio signal. A radio like this is called a digipeater.

Post comments on this article and find any associated files and/or downloads at
www.nutsvolts.com/magazine/article/August2016_Near-Space-Radio-Tracking-With-Quadcopters.

When I'm looking for recommendations involving near space and amateur radio, I go to the best place I know for information: the GPSL email list group. Several list members recommended the T3-301 VHF Data Radio from Argent Data Systems (**www.argent data.com**).

Programming the Argent Digital Radio

The Argent website has the free software you need to program their radio. I installed the software and then proceeded to learn how to use it. Much of it looks like the programming software Byonics includes for their brand of APRS trackers. I found the learning curve for the Argent software to be pretty shallow.

I programmed the following information into the Argent radio:

Callsign for the digipeater (KD4STH-1 for my radio)
Path (WIDE2-1)
Symbol (Helicopter)
Text Message (NearSys Quadcopter)
Text Message (Transmitted as part of the Status Report once every six transmissions)
A Fixed GPS Position (My school)
Telemetry Information (Only radio temperature and battery voltage)

A callsign is required for every amateur radio transmission since amateur radio is a public service and the transmissions cannot be secret.

The callsign is how the public can identify the sender of each radio

The T3-301 VHF Data Radio by Argent Data Systems. The radio is a pretty simple affair — no display and no knobs. The radio is configured using Argent's software.
Image from Argent Systems.
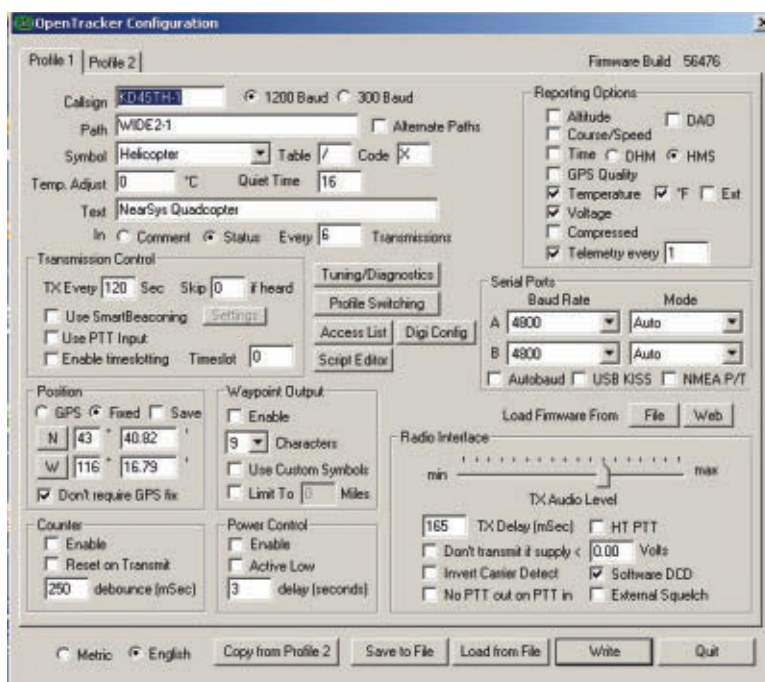
Programming Argent's data radio is as simple as programming the Byonics TinyTrak (although there are many more options with the Argent radio).

transmission. The callsign that the FCC (Federal Communications Commission) assigned me is KD4STH. The SSID I chose for the quadcopter's digipeater is -1. There are 16 SSIDs to select (from -0 to -15) and they let hams use up to 16 digital radios at the same time.

Amateur radio operators often assign SSIDs according to the function of the radio. In my case, I have so many near space trackers that I've started assigning them with less specificity.

The path command limits how many radio stations can retransmit the transmission from the quadcopter's digipeater. Using WIDE2-1 means digipeaters receiving the transmissions from my quadcopter will retransmit it once. That gives transmission from the quadcopter one chance to make it to an IGate and the Internet.

If the WIDE path was changed to something like WIDE3-3, the transmissions from my quadcopter would be retransmitted a total of three times and could potentially fill the radio airways with redundant information. That extra radio traffic would reduce the chances of other amateur radio operators getting their transmissions repeated even once and being heard.

The symbol and text message are just informational and not strictly necessary. Symbols are icons displayed on maps where they become visual clues to the identity of the radio station transmitting. The text allows interested parties to know what kind of device is transmitting the signals and the condition of its battery (important information for me if I start seeing fewer radio messages from the digipeater).

I used a fixed GPS location since the quadcopter's digipeater doesn't

have its own GPS. In a future upgrade, I'll attach a GPS to the radio so anyone can see the quadcopter's current position every time it transmits.

Now the important part: I needed to configure the Argent data radio to digipeat, but only for APRS transmissions coming from near spacecraft.

You can see that I enabled the radio to digipeat transmissions from APRS stations, including the term QUAD in their path.

The digipeater only transmits these transmissions once and because the Exempt option was selected, it doesn't matter where the term QUAD appears in the near spacecraft's path.

Normally, when there are multiple path statements in an APRS transmission, the second or later path statement isn't acted upon until the prior path statement is "used up."

Finally, enabling the digipeater for QUAD meant I also had to change my near space trackers using a path of WIDE2-1 to a path of WIDE2-1 QUAD.
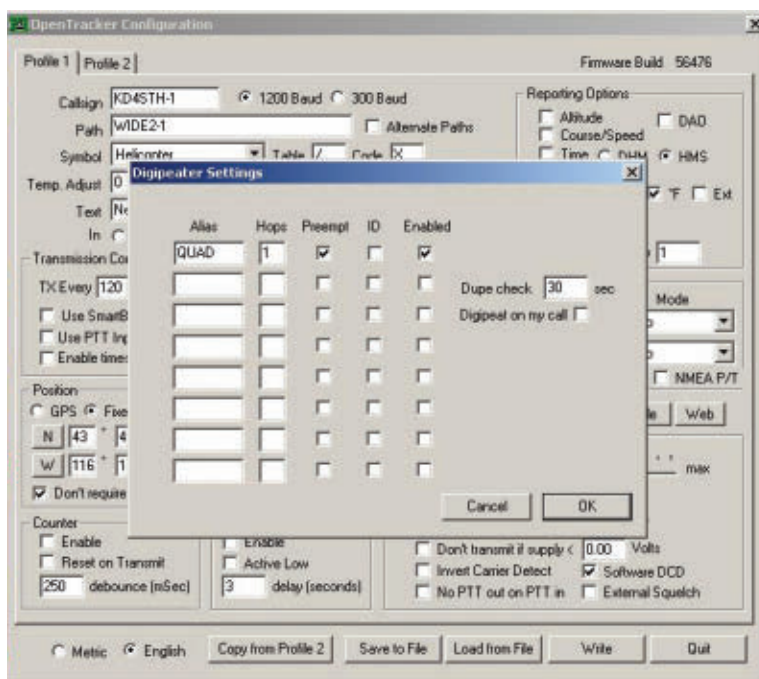
After clicking the Digi Config button, this screen pops up.
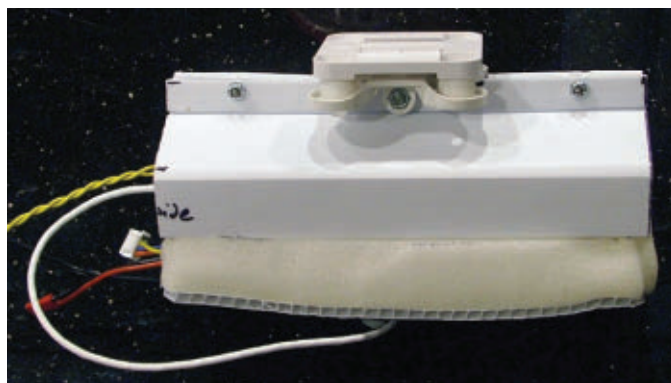
The pallet is a two story affair. The top part holds the radio and the bottom is filled with foam rubber and holds the LiPo battery. The pallet was made from Coroplast because it's easy to machine and is lightweight.

The Chroma — like other quadcopters — has a set of status LEDs. I watched the LEDs for several minutes as the Argent radio transmitted several packets and found no change in status. This was an indication that the digipeater couldn't interfere with the Blade Chroma's flight.

Building a Pallet for the Argent Radio

The six ounce Argent T3-301 data radio only needs a battery and antenna to operate. To keep the mass down, I selected a LiPo battery; specifically, a Venom 800 30C 11.1 volt rechargeable LiPo.

Because the radio is slung beneath the quadcopter, I chose to use a dipole antenna and to mount the antenna horizontally. This insures the antenna stays free of the quadcopter's spinning blades. Besides, most of the time after landing, modules and their antennas are lying horizontally on their sides, so it makes sense to position the antenna horizontally like the antennas of the radio trackers the digipeater is trying to hunt down.

Interference Testing

Based on the advice of Blade and Horizon Hobby, I tested whether the Argent's transmissions would interfere with the Chroma's GPS. If this were to occur, the Chroma would lose its sense of place and require manual flying.

I found a simple way to run the test as you will see next.

Results

I left a near space tracking module in my front yard and then went traveling with the quadcopter, digipeater, and a Kenwood D-72 handheld radio.

The Kenwood incorporates a GPS, so it let me know my current distance from the house as I drove around. I found a quiet stretch of road one mile from the house and pulled over.

I found that after waiting for several minutes, there was no reception of the tracker at home over my Kenwood radio. This is the same situation that chase crews can experience.

I then sent the quadcopter to an altitude of 100 meters and put it into a hover. Within one minute, the Argent radio on board the quadcopter received and retransmitted a position report from
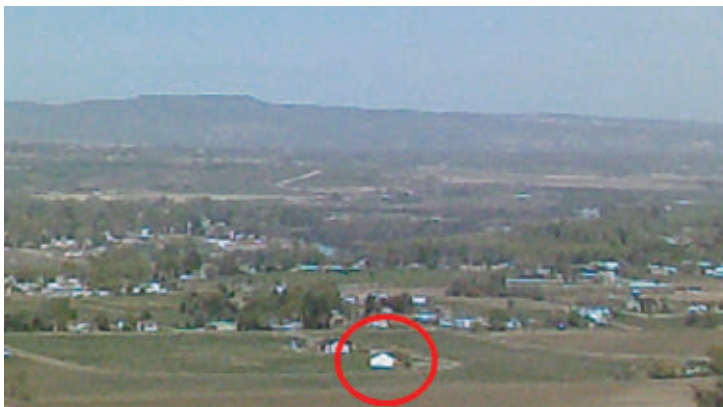
Hey, I can see my house from up here. At one mile away, my handheld radio couldn't receive a position report from the tracker in my front yard. However, the Argent radio on board the quadcopter could. Even better, the quadcopter's radio digipeated the position report to an IGate over 10 miles away.

the tracker at home.

My Kenwood received the digipeated signal from the quadcopter overhead and used that information to tell me exactly where

the tracking module was located.

Final Thoughts

Unmanned Aerial Vehicles (UAVs) or drones are showing amazing capabilities. Now, I don't pretend that helping to recover a near spacecraft is an earth-shattering event. However, if a simple quadcopter can digipeat an APRS signal that's impossible to receive with a handheld radio, then UAVs should be capable of digipeating radio signals in emergency situations. And isn't emergency communications one of the functions of amateur radio?

Onwards and Upwards,
Your near space guide **NV**

Q & A

- ## Solar Heating System Controls
- ## Inertial Navigation System Basics

Solar Heating System Controls

Q I want to build a home heating system that uses solar energy to provide the heat. What types of electronic controls will I need?

Tom Jenson
Gila Bend, AZ

A In **Figure 1**, I show a solar powered residential heating system schematic; in **Figure 2**, I have included a cutaway drawing of a flat plate solar energy collector for reference. The active solar heating system uses a pump to push water or a water/ ethylene glycol (antifreeze) through a series of tubes in the collector. Inside the collector, the water is heated and returned to a storage tank (think battery) until it is used for the heating system.

Water from the storage tank is recirculated back to the collector to improve the system's thermal efficiency and prevent wasting water by using it in only one pass through the system. The storage tank's cold water line is used to keep the tank full in case of evaporation or small leaks in the system which could result in lost water. The pump could be damaged if the storage tank were to run dry, so its level is maintained to protect the pump and insure that hot water is available when needed.

The storage tank may include an electrical heating element like that used in an electrical water heater to provide auxiliary heat when there is not enough sunshine for a couple of days to provide what's needed. The hot water out of the storage tank will be pumped through a heating element(s) in the home (hydronic piping in the floor or air duct heat exchanger) using a separate pump and piping loop before being returned to the storage tank (not shown in the drawing).

In locations where the outside temperature can drop below freezing, the closed loop system with freeze protection is used. In the closed loop system, the water/ glycol mixture can be used in the outdoor loop only so that water from the storage tank can be used for human consumption (ethylene glycol is sweet, so children and animals will readily drink it and be poisoned). The expansion tank is needed to hold the extra volume of water in the closed outside loop which accounts for the increase in water volume as the water heats. Plus, as the expansion tank fills, the air in it compresses and removes any pressure pulses generated by the pump (think filter capacitor).

Passive solar heating systems with fluid stored at a height above the system provide pressure to push the fluid through the system, and gravity-assisted flow (cooler water sinks and warmer water rises) to replace the pump in the outside loop. This reduces electrical costs and complexity, but requires a good structure to hold the stored fluid above the system and requires low pressure loss designs in the piping to function properly.

Designing the solar heating system is well beyond the focus of this column, but here are some design considerations:

Collector Design Factors

- Fluid channels should have high thermal conductivity to allow maximum flow of heat into the water.

■ FIGURE 1. Open Loop Active Solar Energy Residential Heating System.
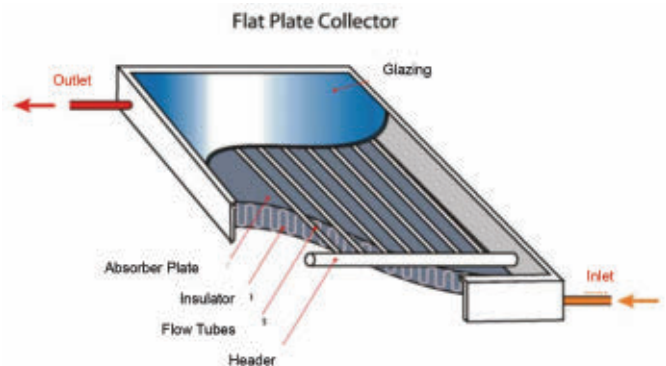
■ FIGURE 2. Solar Energy Collector.

• Glazing should allow maximum solar energy to enter but block heat from escaping to the ambient air.

• Absorber plate should capture as much solar energy as possible.

• Provide insulation that will not absorb moisture under the absorber plate to hold in as much energy as possible.

• Smaller flow tubes provide a larger surface area to volume ratio which will heat the fluid better, but result in a larger pressure loss which requires a bigger pump.

• The area of the collector is determined by the heat requirements which are affected by the amount of sunlight available, the volume of air in the house, and the desired temperature in the house, plus geography, climate, and latitude of the home site.

Piping/Pump Design Factors

• Flow rate of water to the collectors is affected by the amount of heat being collected (size of collectors).

• Larger pipes and fittings reduce the pressure drop and thus pump size, but increase weight and cost of the system.

• The piping must be designed to handle the pressure and temperature of the fluid inside them.

• Insulate the pump and piping to hold in heat.

• The pump should be sized to produce the required flow of water and overcome the pressure drop of the system.

Storage Tank Design Factors

• Storage tank should be designed to handle the temperature and pressure of the fluid inside it.

• Insulate the outside of the tank to hold in heat.

• Provide a drain line to clean out dirt that builds up in the bottom of the tank.

Safety Equipment

• Pressure/temperature relief valve for storage tank and collectors.

A solar heating system requires a much more complex control system than on other residential heating systems such as heat pumps or gas/oil fired furnaces. The heart of the control system is a differential thermostat that measures the difference between the water temperature in the collectors and the water temperature in the storage tank. This is so when the water in the collectors is 10 to 20 degrees Fahrenheit above the temperature in the tank, the pump runs to add warmer water to it. Some controllers support variable speed pumps which improve the efficiency of the system by controlling the water flow rate based on the amount of solar heat present at the collector.

I would like to see a photovoltaic sensor placed on the

solar collectors to modify the speed of the variable speed pump to capture the maximum amount of solar heat and to turn the water flow off when the incoming solar irradiation (insolation) drops below a certain value. Ambient air temperature sensors could be used to shut down and drain the outside loop when the temperature approaches the freezing point. Any outdoor instrumentation and controls should be weatherproofed. If you use zone control in which different areas of the residence have their own heat exchangers or hydronic loops, each of these zones will need an independent thermostat, fans/controls, and water flow valves.

Tim Brown

Inertial Navigation System Basics

Q I have been reading about inertial navigation systems which do not need a radio signal to determine their location. Could you explain these systems?

Nathan Ivester
Colorado Springs, CO

A An inertial navigation system depends on a method of determining speed and distance moved from a fixed point without the need for external signals such as radio navigation devices or GPS device use. First, I will look at navigation principles to make sure everyone is on the same page before moving on to explain how the inertial navigation systems work.

The purpose of navigation is to get from one point to another predictably. **Figure 3** shows a simple navigation example with the dashed line representing the path or course we will take. In **Figure 3**, our goal is to go from Point A to Point B which is a seemingly simple process. To make our navigation problem more useful, we need to consider the direction from Point A to Point B and the distance from Point A to Point B as is shown in **Figure 4**.

■ **FIGURE 3.**
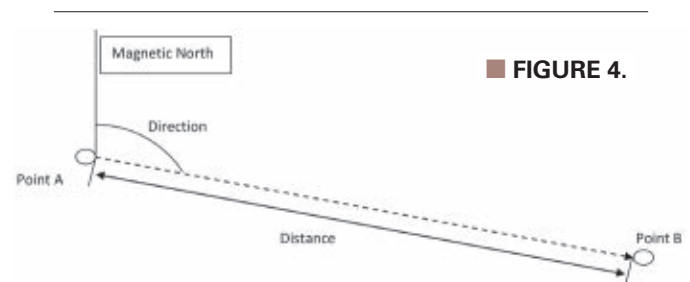
■ **FIGURE 4.**

Example of Calculating Set and Drift of a Current

GPS fix (Actual Position)

5 nautical miles measured with dividers

1 knot of current measured with dividers

Lead angle

6 nautical miles

Dead Reckoning a 1 hour traveling 6 knots

Leeway Correction
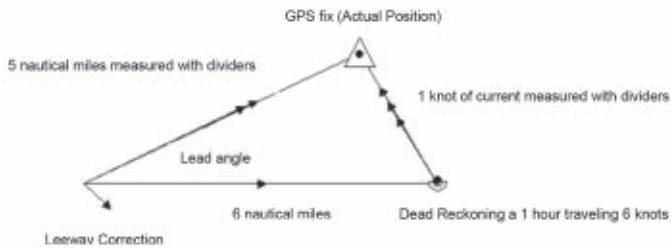
■ **FIGURE 5. Effect of Currents on a Boat's Path.**
set = direction the current flows
drift = velocity of the current

The distance is how far Points A and B are apart measured in miles or kilometers. The direction is the angular measurement between Points A and B, and a reference such as Magnetic North as is used in maps.

If a real navigation problem were as simple as **Figure 4**, we would have no problem navigating anywhere we wanted to go. In the real world, however, things are not quite so simple. A boat moving on the water or an aircraft moving in the air make things a bit more complicated.

Take a look at **Figures 5** and **6** that show the boat and aircraft navigation problems, respectively. The wind and water currents (neither of which is predictable) cause the vehicle to drift from the course it would take with no wind or current which is the course we want to travel. I am an aviator, not a sailor, so some of our readers may need to keep me straight on the nautical aspects of navigation. Wind and tides affect the course of a boat but for this discussion, let's not add those complications.

Dead reckoning is a means of navigation in which the speed of the vehicle, the desired direction of travel (the course), and the wind/current effects are used to

V_{PA} = velocity of aircraft with respect to air

V_{PA} airspeed wind velocity V_{AG}

Resultant ground speed V_{PG}
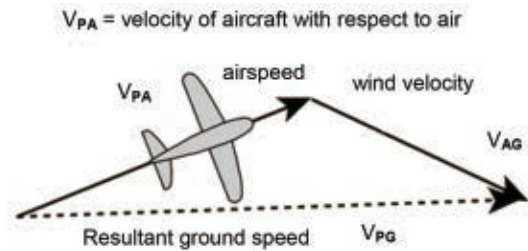
■ **FIGURE 6. Effects of Wind on Aircraft Flight Path.**

calculate the actual direction the vehicle should be pointed (heading) and the time required to reach the destination (very important in managing fuel on board requirements). Dead reckoning would be used in all forms of navigation if the wind/current, vehicle speed, and magnetic course were constant. Unfortunately, the wind/current changes, often dramatically over the route of travel. The vehicle speed can change due to wind/current, vehicle weight, and power plant variations which further render dead reckoning not as accurate as desired.

Figure 7 shows a dead reckoning course as the brown line and another form of navigation – pilotage – as an orange line. Pilotage involves finding a course from the start to the destination by moving between easily recognizable landmarks such as road crossings, railroads, etc., for aircraft. Cruise missiles use a form of pilotage using digitized terrain maps combined with GPS and radar/atmospheric altimeters to navigate accurately to their targets.

Radio signals greatly improve navigation when implemented in VHF Omni-Range (VOR), non-directional beacons/automatic direction finders, and Loran and Global Positioning Systems (GPS). **Figures 8**, **9**, and **10** show the basics of the VOR, LORAN, and GPS navigation. The VOR operates on a phase variable signal transmitted by the

■ **FIGURE 7. Aeronautical Navigation by Dead Reckoning (Brown Line) and Pilotage (Orange Line).**
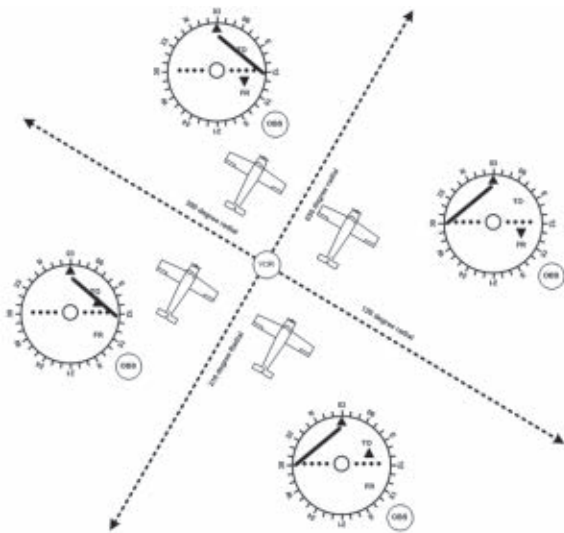
■ FIGURE 8. VHF Omni-Range (VOR) Radio Navigation.
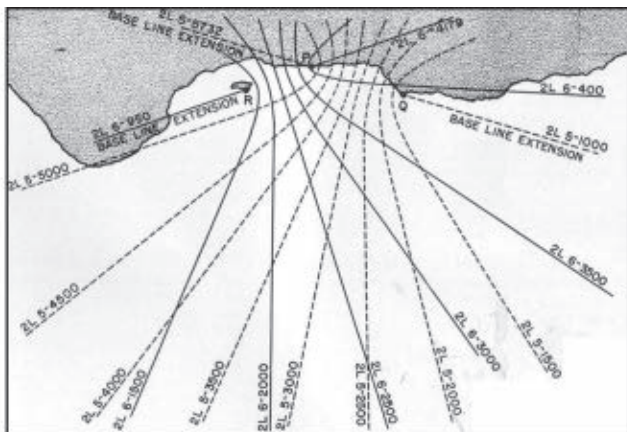
■ FIGURE 9. LORAN Station Arrangement.
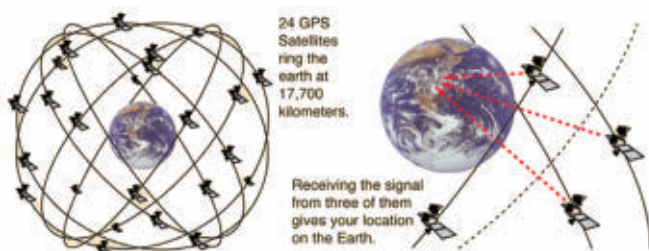
■ FIGURE 10. Global Positioning System Navigation.
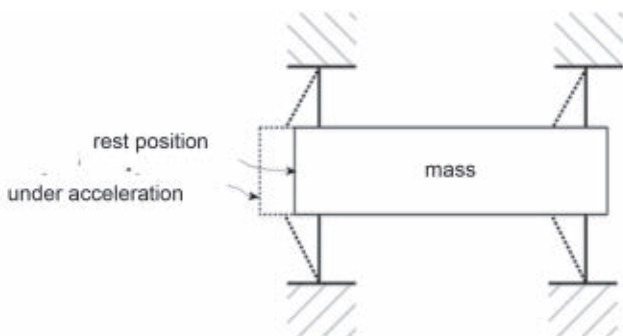
■ FIGURE 11. Basic Operation of an Accelerometer.

VOR station that represents the bearing from the station to the airborne receiver. The LORAN system operates by the shipboard receiver determining the time delays of signals transmitted from two LORAN stations. The GPS operates by the receiver comparing the time differences and satellite positions of at least three satellites. LORAN and VOR systems can be used to determine the position of a vehicle, while GPS can also determine altitude which is useful for aircraft and hikers in the mountains.

One of the earliest forms of long distance navigation was celestial which involves using dead reckoning to estimate a future position, calculating the position of easily identifiable stars, and then comparing the actual position of these stars to determine the actual position. Celestial navigation uses complex math (hyperbolic trigonometric functions), data tables of star positions at various times of the year (Nautical and Air Almanacs), and precision time pieces. Celestial navigation is a very complex subject which takes several months of training to master, so I will steer (very punny) clear of the subject.

All of the forms of navigation rely on a measure of the speed of the vehicle, the direction of travel, the time of travel, and a reference such as a map. The accuracy of your navigation depends on the accuracy of these pieces of data.

Now that we have a very basic understanding of navigation (there is a lot more to navigation than I am giving you here), let's look at the Inertial Navigation System (INS). The INS measures the vehicle speed, from which distance traveled is calculated using an accelerometer and some electronics. **Figure 11** show a very basic accelerometer in which a mass – which tries to stay in the same position as the vehicle accelerates -- has a distance change (displacement) relative to the main body of the accelerometer. In **Figure 11** as the vehicle accelerates to the right, the mass moves to the left of its rest (not accelerated) position. The four mass supports provide a spring action which allows the distance the mass moves to be relative to the amount of acceleration.

The accelerometer in **Figure 11** needs an electronic means of determining the displacement of the mass such as a potentiometer, capacitance (mass moves the plate closer to one plate and farther from the other), a linearly variable differential transformer (LVDT), or a piezoelectric material implemented as micro electro-mechanical systems (MEMS).

Figure 12 shows a capacitive MEMS accelerometer sensor in simplified diagram form. These MEMS accelerometers are used in electronic items to determine the orientation of the device in order to present the display in the proper orientation.

To determine the distance a vehicle has traveled using the accelerometer signal, we need some electronic circuits to convert the acceleration output from the accelerometer sensor to a measure of distance. Acceleration is the rate
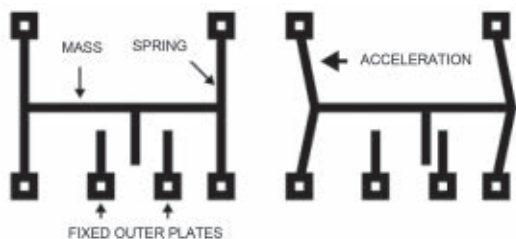
■ **FIGURE 12. Capacitive MEMS Accelerometer Operating Diagram.**

of change of velocity (speed), so we need a circuit which converts the rate of change to velocity. Likewise, velocity is the rate of change of distance, so we need a similar circuit to convert this rate of change of distance to distance traveled.

There is a mathematical process called integration which will do the job. Basically, integration takes a rate signal and adds it up over time to determine a result. This is like a gasoline pump meter at the local service station. The gasoline is pumped at a certain rate (gallons per minute) and the meter "accumulates" this flow rate over the time you are pumping to determine the number of gallons you have pumped. An electronic integrator is built using an operational amplifier (op-amp) with a capacitor in the feedback loop instead of a resistor.

To obtain distance traveled from acceleration, we need a double integrator as shown in **Figure 13**. The position output of **Figure 13** represents the total distance traveled over the time interval of concern, and the velocity output represents the speed at the present time. The outputs
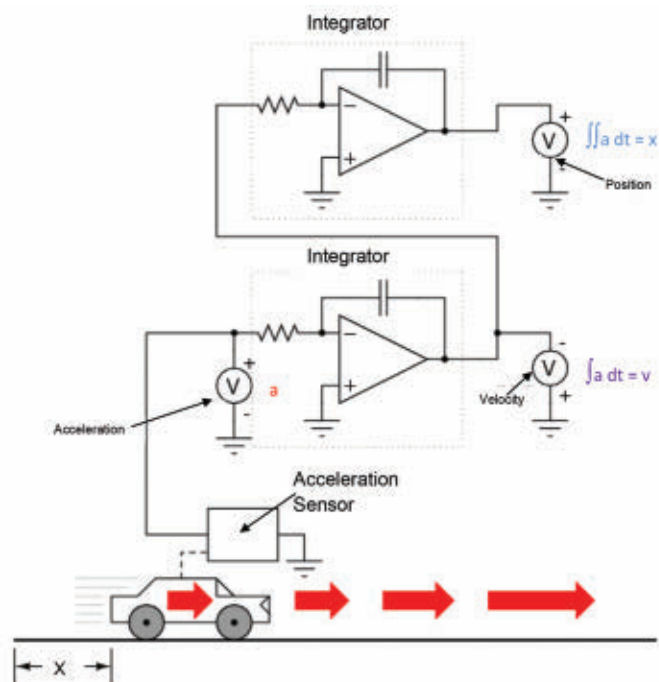
■ **FIGURE 13. Calculating Position Using an Accelerometer.**
∫f(x) dx means to integrate the f(x) [y-axis function values related to the x-axis values - basically finds the area under the f(x) curve along the x-axis]

from the accelerometer sensor and the double integrator circuit are analog (continuous) signals, so to be used by a microcontroller or PC these signals must be sent to an analog-to-digital converter (ADC) to create the digital representation of speed and position.

By starting the distance calculation from a known position, we can determine our location after a period of time. It's kind of like the old pirate's map instruction: Starting at the coconut tree, walk 10 paces due east.

Thus, we have developed a means of determining distance traveled for a vehicle using a one-dimensional (1-D) motion mode of operation. However, in the real world, we need two-dimensional (2-D) motion information for surface vehicles, and three-dimensional (3-D) motion for aerial vehicles. This is where things start to get really complicated really fast.

In 1-D motion, the orientation of the acceleration never changes. It is either forward or backward but never side-to-side or up-down, so it is very easy to keep the accelerometer's sensing axis aligned with the direction of travel. In 2-D and 3-D motion, we need a means of keeping the accelerometer sensors aligned with their original orientations or the distances traveled are meaningless. From our pirate's map example: Now, take 10 paces due south and climb 10 feet up the palm tree. If I had not specified the "orienting" directions, we would never be able to find the buried treasure.

Figure 14 shows the 3-D Cartesian coordinate system (or reference frame) in which X represents side-to-side motion; Y represents backward and forward motion; and Z represents up and down motion of our vehicle. A simple solution is to mount three accelerometers on our vehicle,
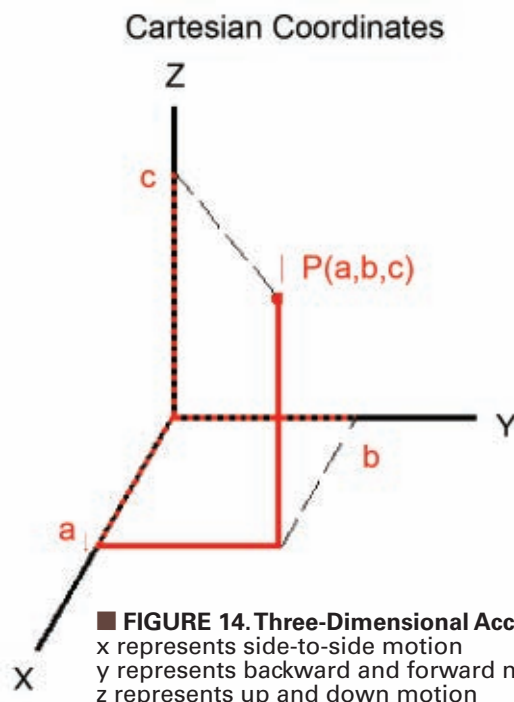
■ **FIGURE 14. Three-Dimensional Acceleration.**
x represents side-to-side motion
y represents backward and forward motion
z represents up and down motion

Gyroscope

$L = I\omega$

Angular Momentum

Spin Axis.

The rapidly spinning inner wheel will maintain its original direction in space if the outside framework changes.
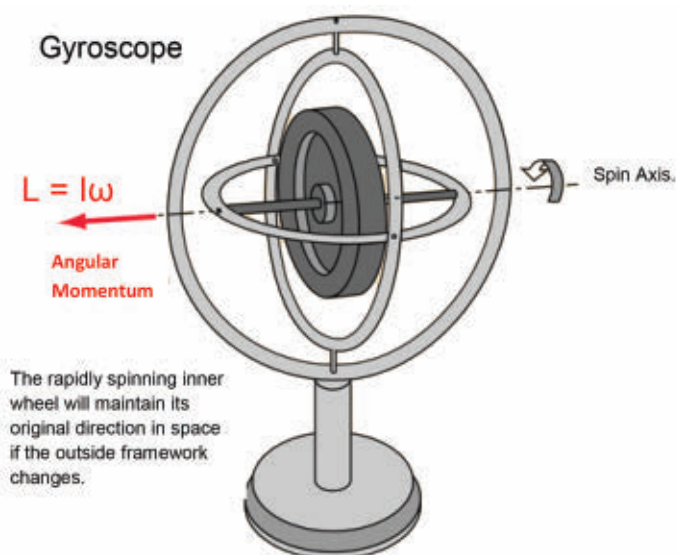
■ **FIGURE 15. A Gimbal Frame Allows a Gyroscope to Maintain Orientation during 3-D Motion.**

Sensor Electronics
Computer
X Accel
X Gyro
Y Gyro
Y Gyro
Y Accel
Z Gyro
Z Accel
Vehicle
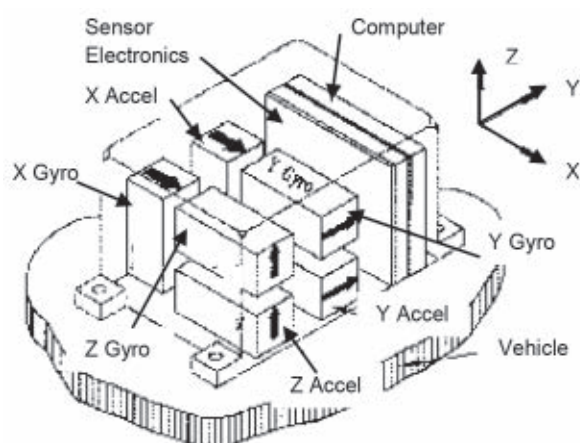
■ **FIGURE 17. Strapdown Inertial Navigation System uses Gyro Error Signals to Correct for 3-D Vehicle Motion.**

Nickel Tuning for Gyro Type 7

■ **FIGURE 18. Tuning Fork Type MEMS Gyroscope.**

Accelerometers
Azimuth motor
Gyros
Roll motor
Pitch motor
Mounting frame
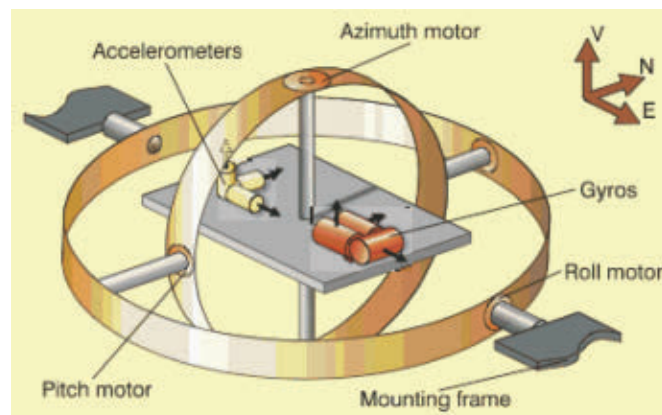
■ **FIGURE 16. Gyroscope Based 3-D Inertial Navigation System.**

each with an axis parallel to the X, Y, and Z reference axes. This would only work if the vehicle never turns or climbs an incline, which would instantly reorient the accelerometer sensor's sensing axes. We need another component to keep the orientation of the accelerometers constant regardless of the motion and orientation of our vehicle.

The gyroscope (a.k.a., gyro) incorporates a rapidly spinning mass that has the property that it maintains a fixed orientation in space. **Figure 15** shows a basic gyroscope mounted in a gimbal frame that allows the gyro to maintain a constant orientation during 3-D motions of our vehicle. It is now obvious that if we mount three accelerometers on three gyroscopes with sensing axes and rotation axes oriented along the X, Y, and Z axes, we will be able to determine the distance our vehicle has traveled.

Figure 16 shows a practical implementation of the 3-D INS in which any motion that affects the orientation of the INS causes error signals to be generated by the gyroscope which, in turn, drives servo motors that reorient the INS housing to maintain the accelerometers in their original orientation.

Using actual rotating gyros requires a lot of mechanical fabrication and precision which lends itself to numerous potential for errors and their ensuing inaccuracies. As electronics people, we would like a more electronic and less mechanical INS (less failure prone). The strapdown INS shown in **Figure 17** is attached to the vehicle and the error signals from the gyros are fed to the computer with the accelerometer signals to determine the vehicle's position regardless of orientation changes.

Earlier, we looked at the MEMS accelerometer which limited the mechanical elements, improving its accuracy and reliability, plus reducing its size which allowed it to be fabricated in IC chip form. We can fabricate a MEMS gyroscope using a cylindrical resonator, wine glass resonator, vibrating wheel, or tuning fork arrangement etched into a silicon substrate. The MEMS gyro uses a piezoelectric element to generate an electrical signal which represents the rotation of the gyro. **Figure 18** shows the

■ **FIGURE 19. Block Diagram of Maxim MAX 21100 Inertial Measurement Unit.**

actual tuning fork gyro fabricated on a substrate.

Wouldn't it be wonderful if we could buy a complete MEMS INS encased in a single integrated circuit chip? **Figure 19** shows the block diagram of a Maxim MAX 21100 integrated circuit Inertial Measurement Unit (IMU — the sensor portion of the INS). The MAX 21100 IMU (which sells for less than $6) incorporates accelerometers, gyros, and ancillary electronics which take the gyroscope, accelerometer, and external magnetometer raw data as inputs and provides the device orientation information as output. This orientation data could be used by a microcontroller or PC to calculate a vehicle's position, speed, and altitude using the appropriate user-generated software.

I hope I have given you enough insight into the world of navigation and the operation of an Inertial Navigation System so that readers can get started incorporating the IMU into their drones or mobile robot projects.

Tim Brown

Figure *Credits*

2. www.newmexicosolarandwind.com/Solar%20Thermal.htm
5. www.bananawind.us/Basic_Navigation.htm
6. http://hyperphysics.phy-astr.gsu.edu/hbase/airpw.html
7. www.recreationalflying.com/tutorials/navigation/route.html
8. www.langleyflyingschool.com/Pages/PPL%20GS%20Radio%20Navigation.html
9. www.lr.ttu.ee/~juliad/IRZ0050/pdf/IRZ0050_7L.pdf
10. http://hyperphysics.phy-astr.gsu.edu/hbase/gps.html
11. http://soundlab.cs.princeton.edu/learning/tutorials/sensors/node9.html
12. www.mouser.com/applications/mems-overview/
13. www.allaboutcircuits.com/textbook/semiconductors/chpt-9/computational-circuits/
14. http://electron9.phys.utk.edu/vectors/3dcoordinates.htm
15. http://hyperphysics.phy-astr.gsu.edu/hbase/gyr.html
16. https://leagueofextraordinarytechnicians.wikispaces.com/Inertial+Navigation+Systems+-+Operation+%26+Testing
17. http://xenia.media.mit.edu/~verp/projects/smartpen/node8.html
18. https://www.quora.com/How-does-a-MEMS-gyroscope-work
19. https://www.maximintegrated.com/en/products/analog/sensors-and-sensor-interface/MAX21100.html
Figure A. Circuit provided by Rick Swenton

MAILBAG

Furnace Data Acquisition

#1 I would like to comment on your recent response to Furnace Data Acquisition. Your circuit as drawn will not work. The left sides of the bridge rectifiers need to connect to terminals Y and W, respectively, and not to Rh and Rc. If wired as shown, the rectifiers will have 24VAC on them all the time and will not be going on and off with the thermostat signal.
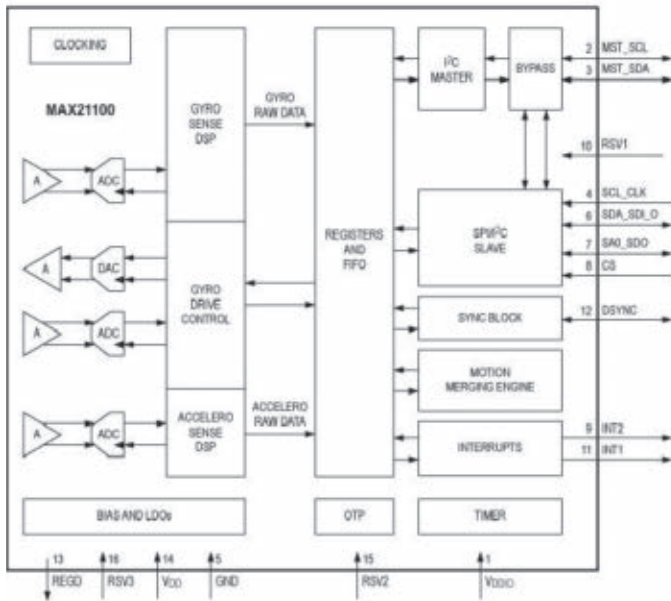
There are many ways to monitor the thermostat signals. While your circuit will work, I would not have done it this way. I would use an optocoupler. With an optocoupler, the connection between the heating system and the Arduino (or whatever you use as a controller) will be completely isolated. There is no direct connection between them as the signal is coupled by light. Further, the optocoupler output is open collector. The pull-up resistor can be tied to any voltage you need (such as 3.3 volts) without changing any circuit components. My circuit also provides noise immunity as any noise in the heating system will not pass through the optocoupler. Who knows if the heating system relays have back EMF diodes on them? Almost any optocoupler will work here.

If you want to monitor both heating and cooling, you need to build two of these. The one shown in **Figure A** is for heat. The second one would connect to the Y wire instead of the W wire. Many installations do not have a C wire at the thermostat. It is usually black or blue. If you have an electronic thermostat and you want it powered by the heating system and not running on batteries, you either need a C wire or you would have to run a new power wire from an AC adapter to the thermostat. If your thermostat does not have the C wire, you can install this circuit near the heating system where the C wire is available.

A word of caution about that jumper between Rc and Rh. That jumper should only be installed on a system that provides both heating and cooling from the same single system with one transformer. In the case of having separate heating and cooling systems with two transformers, the heating system will provide the Rh wire and the cooling system will provide the Rc wire. In this case, the jumper should be removed. If you leave the jumper connected, it will cause the transformer secondaries to be in parallel. If the transformers are out of phase, they will burn up because you will have a 48 volt short circuit. Many thermostats come with this wire already installed.

Another note is concerning the optocoupler. If you plug in the optocoupler with the circuit powered up, you will blow it. Without U1 connected, the capacitor C1 will charge to about 34 volts. If you plug in U1, there may be a puff of smoke. With U1 connected, the capacitor will charge to less than one volt.

Rick Swenton
Bristol, CT

*Rick, you must be looking at the schematic in the February 2016 Q&A. I corrected the schematic using the Rh and Rc terminal connection in the May 2016 Q&A (**Figure B** in this issue's Q&A) and confessed that I am not an HVAC person. Optical isolators (another name for optocouplers) are a great way to couple power line operated circuits to a microcontroller. The optical isolator breaks the electrical*

Solar Heating System Controls

Collector Plate Design
www.powerfromthesun.net/Book/chapter06/chapter06.html
Pump and Piping Design
www.pua.edu.eg/PUASite/uploads/file/Engineering/Fall%202012/ME%20332/Piping%20I.pdf
Instrumentation and Controls
www.solarpanelsplus.com/products/solar-thermal-controls/
www.steca.com/index.php?Solar_controllers_temperature_differential_control
Solar Heating System
www.builditsolar.com/Projects/SpaceHeating/Components.htm
Solar Water Heaters
http://www.asse-plumbing.org/chapters/%5CNOH%20SolarWtrHtg%20Pres.pdf

Inertial Navigation System Basics

Accelerometers
www.omega.com/prodinfo/accelerometers.html
www.vernier.com/products/sensors/accelerometers/3d-bta/
www.memsic.com/accelerometers/
Gyroscopes
www.youtube.com/watch?v=cquvA_IpEsAhyperphysics.phy-astr.gsu.edu/hbase/gyr.html
www2.st.com/content/st_com/en/products/mems-and-sensors/gyroscopes.html?querycriteria=productId=SC1288
Inertial Navigation Systems
www.maximintegrated.com/en/products/analog/sensors-and-sensor-interface/MAX21100.html
www.fairchildsemi.com/product-technology/mems-imu/
www.cytron.com.my/c-411-accelerometer-gyro-imu
www.mouser.com/ProductDetail/Maxim-Integrated/MAX21100+T/?qs=ooqgTKD20do3XP1JHMnqFg%3D%3D
www.digikey.com/product-detail/en/maxim-integrated/MAX21100%2BT/MAX21100%2BT-ND/4914869

connection between the higher voltage line circuit and the lower voltage microcontroller, which protects the microcontroller from voltage spikes on the line side when the HVAC unit starts. Additionally, the optical isolator limits -- if not eliminates -- noise in the signal line to the microcontroller and can be used to convert between two different voltage systems such as 12 VDC from a sensor to 5 VDC to the microcontroller input. The optical isolator can also pass AC signals which lend them to applications such as audio systems. I taught robotics and automation at a community college for 20+ years and always recommended optical isolators on every signal line to the controller.

For those not familiar with optical couplers, I will give a little information on their operation. In **Figure A**, the optical isolator is U1, a 4N25 six-pin through hole DIP IC package. The 4N25 input side has an LED which turns on when the LED is forward biased by the input signal and emits a light signal inside the IC chip. The phototransistor in the 4N25's output circuit turns on when this light is present, and in the circuit shown drops the voltage on the signal line to the microcontroller to near zero. If you need an active high signal to the microcontroller, you can insert an inverter (better to program the microcontroller for the active low signal thus reducing the parts count and its ensuing failure potential).

Tim Brown

#2 In **Figure A** on page 16 of May 2016: The connections to the 7805s seem to be wired on the wrong side of the switch and the labels are incorrect going into the GPIOs. "Heat" should
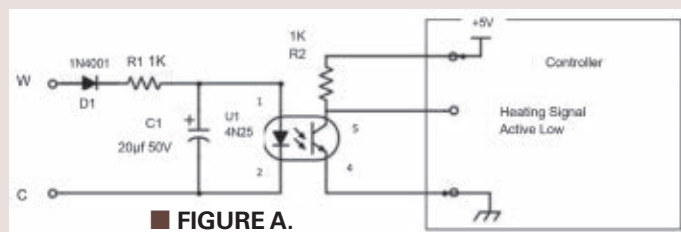
be "Cool" and "Cool" should be "Heat." Hopefully, the μC GPIO inputs are 5V and not 3.3V.

Marc Forgey
via email

Marc, you are quite correct. I accidently reversed the labels on the microcontroller when drawing the schematic. I have corrected the schematic in **Figure B**. See the reply above from Rick Swenton for using optical isolators on the inputs to the microcontroller to protect the microcontroller from voltage spikes and reduce noise to the μC.

Tim Brown

#3 At the end of your piece on battery life, I believe there's a typo. It shows: 250 mA - 2.50, 100 mA - 0.32 and 50 mA - 0.43. I believe the first should have been: 250 mA - 0.25.

Philip Karras
via email

Phillip, you caught my decimal malfunction. I decided on a better way of presenting this information: Load Current (mA) - Amp Hours (AH) @ 250 mA - 0.25 AH; @ 100 mA - 0.32 AH; and @ 50 mA - 0.43 AH. Thanks for catching my mistake.

Tim Brown
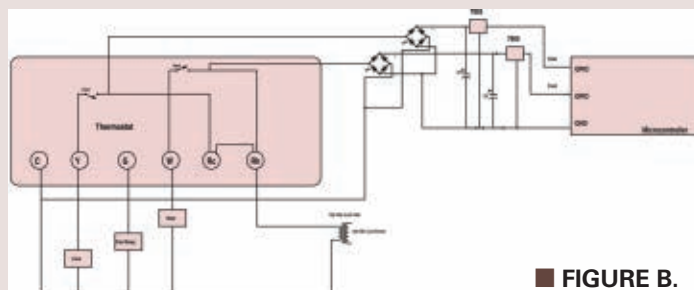
■ **FIGURE A.**

■ **FIGURE B.**

NEW PRODUCTS

X-RAIL EXTRUSIONS, MOUNTS, AND ROLLERS

Actobotics newest X-Rail extrusion complements the already extensive building system. The 'X' profile provides a slot in the center of each of the sides to capture the mounts to solidly fasten various components. While that might exhaust the ingenuity of other brands of extrusion, the Actobotics X-Rail has other key features that increase the versatility.

The 1/4" bore is convenient for locating an axle in a rotating assembly; routing wires, cables, or hoses through; or could even be tapped (5/16-18 tap size). Around the 1/4" bore is a .770" Actobotics pattern with the proper hole-diameter (.1065") to accept a 6-32 tap to fasten channel, plates, and brackets to the ends easily. Even if it becomes necessary to cut down the X-Rail extrusion, all of those features remain.

Also, drill guides are formed into each of the sides on center and on the 'flats' containing the .770" hub pattern so if you need to drill, your bit won't wander.

Dimensionally, the X-Rail is exactly half the size of the channel so that the geometry remains correct for expanding an assembly with additional Actobotics parts. The X-Rail is constructed of 6061 T6 aluminum. Prices are $5.99 for 24"; $8.99 for 36"; and $11.99 for 48".

Actobotics' X-Rail mounts allow you to integrate the X-Rail extrusion with the Actobotics building system. The mounts will self-align when an Actobotics component is attached using 6-32 screws. Parts will be securely held in place as the mounts

sit just below the top surface of the X-Rail, causing the mount and the attaching part to sandwich the extrusion.

Dual mounts have the .770" pattern as well as the side of the 1.5" hub pattern (measuring 1.0607") and one hole right in the center. The single mounts can be spread to any desired distance and used in pairs to fasten items no matter how far the attaching holes are spaced apart.

The mounts are machined from 6061 T6 aluminum for excellent strength and durability. Pricing is $2.99/pair or $2.99/four-pack.

The Actobotics X-Rail roller bracket further complements this building system. You can create an extremely smooth slide system when combined with the roller brackets. Pricing is $9.99/pair.

HERMETICALLY SEALED CAPACITORS

Cornell Dubilier Electronics, Inc. (CDE), introduces its Slimpack, type MLSH: the first in a series of hermetically sealed aluminum electrolytic capacitors that the company plans to introduce over the next several months. With its glass-to-metal seal that prevents dry-out, this capacitor technology has extraordinarily long life to meet the most demanding applications.
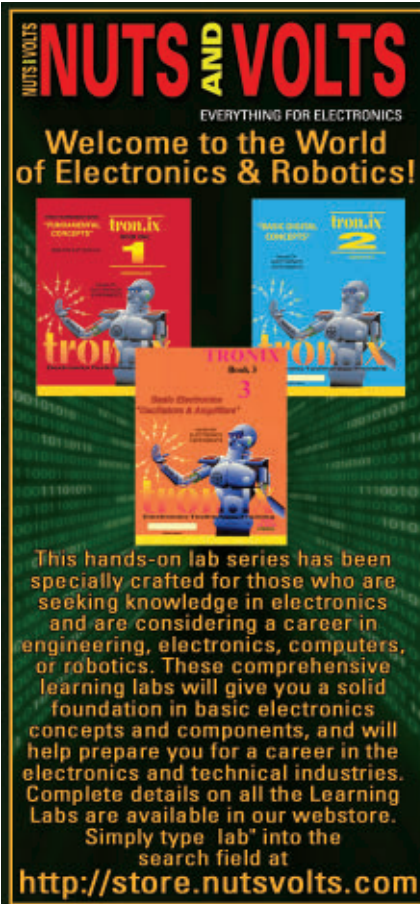
The hermetic Slimpack is a spin-off of the non-hermetic Flatpack series that the company has been supplying to military and aerospace customers for more than 20 years. The company expects this

technology to replace parallel and series banks of wet tantalum capacitors for new and existing designs — especially where bulk storage is paramount. According to the company, the MLSH Slimpack (measuring 1.0" x 1.5" x 0.5") will weigh less and will have more capacitance than a parallel bank of three or more wet tantalum capacitors as at -55°C. High capacitance at low temperature is a key requirement for power supplies used in military and aerospace applications.

In addition to its performance advantages at low temperature, the technology is expected to have a significantly lower cost than a comparable bank of wet tantalum capacitors.

For more information, contact:
Cornell Dubilier Electronics, Inc.
www.cde.com

DIGITAL SERVO PROGRAMMER AND
UNIVERSAL SERVO TESTER

Hitec's lightweight HFP-30 digital servo programmer and universal servo tester is their latest offering in digital servo testing and programming. Packed with advanced features and a large easy-to-read LCD screen, it efficiently programs all Hitec digital servos, including the HS-5XXX, HS-7XXX, brushless HSB-9XXX, and the latest D-Series. Operating on a wide voltage range of 4.8~8.4, the Hitec HFP-30 is a must-have accessory. The HFP-30 field programmer's estimated price is $79.99.

For more information, contact:
Hitec RCD USA, Inc.
www.hitecrcd.com

DAQ SYSTEM LEVERAGES CELL PHONE TECH

DATAQ Instruments announces the release of their model DI-2108 USB data acquisition (DAQ) system that leverages cell phone technology to deliver industry-leading price/performance. Priced at $259, the model DI-2108 provides eight analog input channels each with a

Low Cost PC Two-Channel
OSCILLOSCOPE

By Ron Hoffman
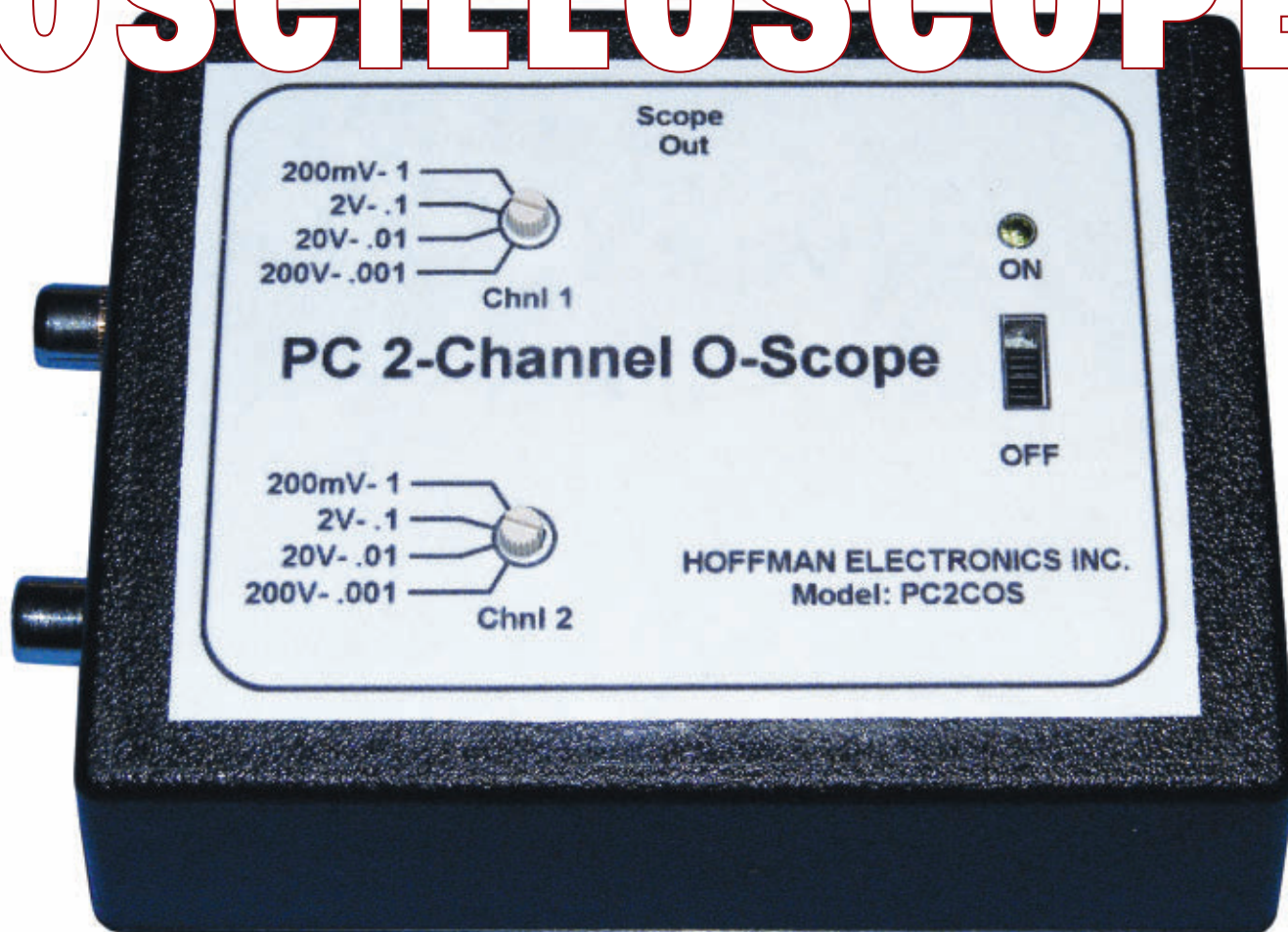
It is said that need is the mother of invention. Recently, I had to troubleshoot some
IR obstruction sensors used with my garage door opener. In order to operate in
bright daylight, they use pulsing infrared light beams to detect an obstruction near
the garage floor. I installed a new pair and aligned them correctly. They worked, but
only intermittently. I checked the obvious things like loose connections and correct
wiring. When it was warmer, they worked okay, but when it got colder, they were
intermittent even when no obstruction was present. This prevented the garage door
from going down and caused a reversal.

Since the output of the IR sensor unit was a pulsed waveform, I needed to look at the output waveforms to determine what was wrong. I thought about dragging my Heathkit two-channel 20 MHz CRT oscilloscope out to the garage and hooking it up, but decided there had to be an easier way. Have you seen the prices on small handheld DSOs (Digital Storage Oscilloscope)? I thought there had to be a simple low cost alternative for solving my problem.

This is where the mother of invention part comes in. I had a program called Soundcard Scope by Christian Zeitnitz. This would work, but might cause serious damage to my HP laptop if the input were overloaded. Also, it would be nice to select input voltage ranges as needed. What I decided to implement was an interface circuit that would allow me to use my external microphone input and Soundcard Scope program to observe low frequency waveforms from my garage door obstruction sensors.

I designed the interface circuit to have a very high input impedance (10 megohms), four range selections (200 mV, 2V, 20V, and 200V per division), a buffered protected output, inexpensive RCA phone jack input connectors to work with low cost "homebrew" probes, BNC to RCA adapters to allow use with standard oscilloscope probes, and an 1/8" stereo patch cable to connect the interface module to the laptop external microphone jack.

■ **FIGURE 1. PC oscilloscope circuit.**
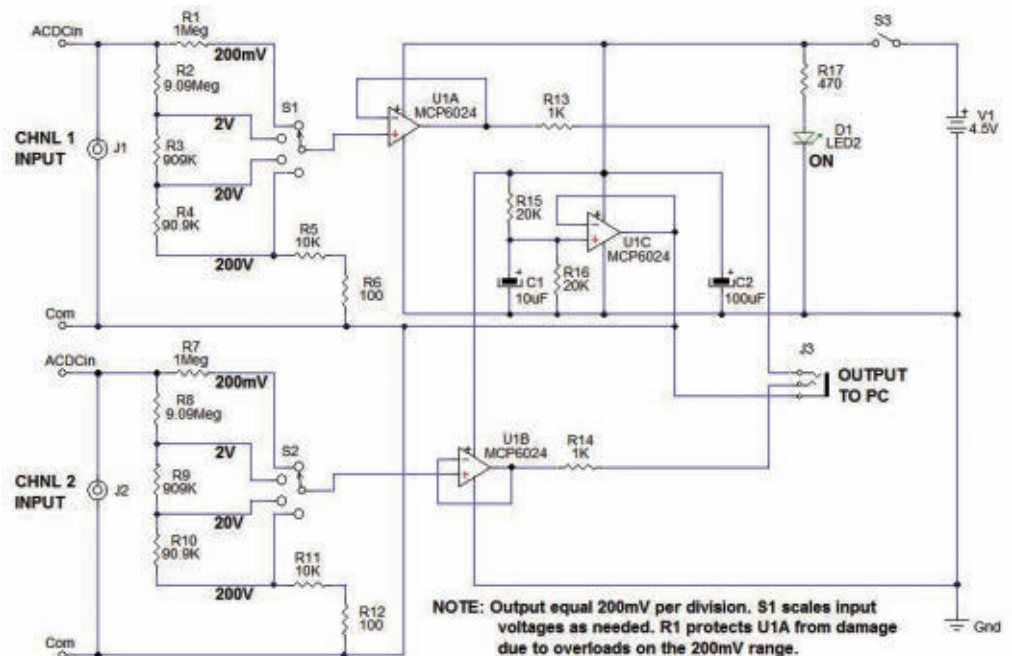
■ **FIGURE 2. Alternate divider network.**

Theory and Operation

Please refer to **Figure 1** (schematic) for this discussion. The PC oscilloscope consists of two components. The first is a PC, laptop, tablet, or tower. The second one is the two-channel probe interface circuit that was designed to scale the input voltages as needed, and protect itself and the laptop from overloads and damage.

The inputs connect to the junction of R1, R2 (channel 1), or R6, R7 (channel 2). The rest of this discussion will pertain to channel 1, understanding that channel 2 is
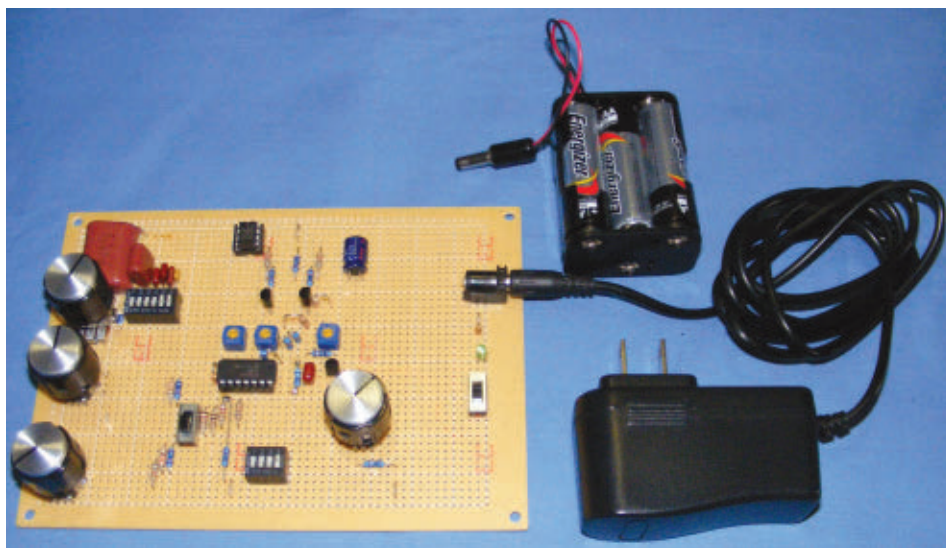
■ FIGURE 3. Sine, square, and triangle function generator.
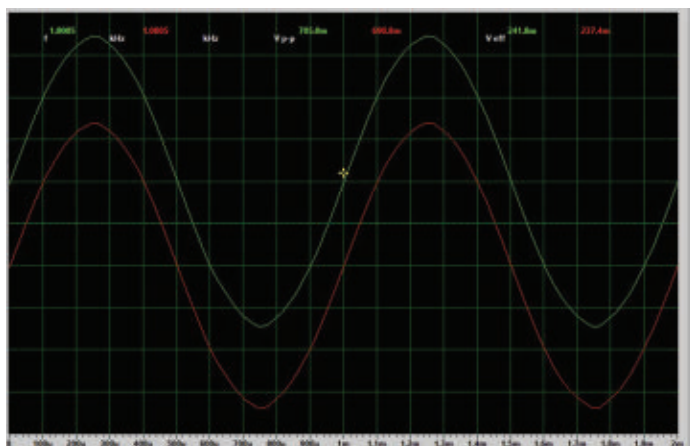
■ FIGURE 4. I kHz at .67% THD.

identical in function and operation.

When selector switch S1 is at the 200 mV setting, the input voltage is connected to the input of U1A via R1. U1A is used as a unity gain buffer. R1 limits the input current to a safe level that can be clamped by the internal MCP6024 protection diodes (±2 mA). Therefore, any voltage less than 2,000 volts will be safely handled by the U1A inputs.

The output of U1A passes through R6 and R10 (not shown) to the 1/8" (3.18 mm) stereo output jack. This limits the output current to 6 mA if both outputs were shorted. That is well below the 20 mA rated output current. S1 connects the input of U1A to a standard 10 megohm divider network. The nine meg, 900K, 90K, 10K 1% resistors scale higher input voltages into a manageable 200 mV range. I had trouble finding the resistors for the divider network as described, but was able to find these values which provide the same .001, .01, .1 divide ratios: 9.09 meg, 909K, 90.9K, 10K + 100 ohms. This alternate

divider version is shown in **Figure 2**.

By setting the Soundcard Scope to 200 mV per division, the divisions will now be equal to the setting of switch S1. The full range of the scope display will be plus or minus 1V, 10V, 100V, or 1,000V. This is useful for measuring higher voltage signals.

There is a frequency limit to the Soundcard Scope. This is due to the sampling frequency of the 16-bit or 24-bit (depending on your computer hardware) A/D used in the sound card, which is 44.1 kHz. It is good to only about 20 kHz, so it is good for most audio signals and lower frequency signals like the garage door sensors. It works well with PWM motor drive signals below 20 kHz, LED and fluorescent lighting ballasts, and other lower frequency signals.

I tried it out with my homebrew function generator (see **Figures 3** and **4**) to see how well it performed over a frequency range from 1 Hz to 40 kHz. The results showed it worked well for sine waveforms up to 5 kHz, and up to 20 kHz for square and triangle waveforms. The other limitation of the PC o-scope is that the PC mic inputs are capacitively coupled, thus limiting low frequencies below 8 Hz and no DC voltages to be measured.

Op-amp U1C acts as a Vdd/2 voltage reference that is connected to the bottom of the input divider network and the output common. This centers the output of U1A and U1B at Vdd/2 and 0V with respect to the common output. The interface is powered by three AAA batteries. They last a long time due to the very low current that's being drawn by the MCP6024. It is less than the current drawn by the power indicator LED D1.

The entire interface circuit draws only about 10 mA when on. The unused op-amp U1D is connected as a unity gain buffer, and the + input is connected to the output of U1C, or Com.

Building the PC O-Scope

The intention was to use inexpensive readily available parts to build the PC two-channel o-scope. All of the resistors are metal film 1% for the input resistive divider, as well as the R15, R16 reference divider. J1, J2 are standard RCA female chassis mount jacks. J3 is a 1/8" stereo jack. Nearly any type of case could be used to house the circuit. I chose a SERPAC Model 032 plastic case left over from a previous project.

The board was sized to use the mounting bosses in the case. The three jacks were mounted to the side walls of the case. The AAA battery holder lays atop of the PCB and is
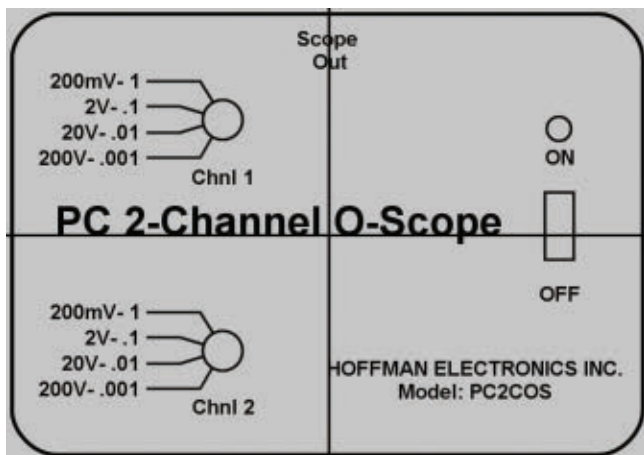
■ **FIGURE 5. Machining label.**
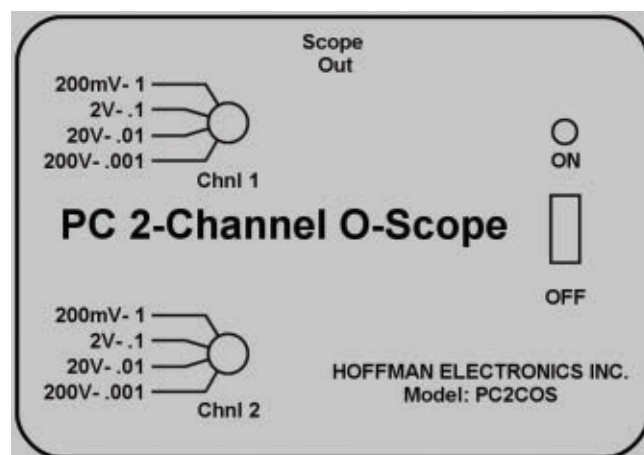
■ **FIGURE 6. Enclosure label.**

held in place with a layer of packing foam rubber. The enclosure machining and case labels are shown in **Figures 5** and **6**.

The machine label has two center lines used to orient the label on the enclosure. Measure to locate the center point of all four sides of the enclosure near the edges. Align the machine label with the marks, then attach it with tape as shown in **Figure 8**. After the machining is complete, remove the machining label and replace it with the enclosure label. Use adhesive laminate over the label to protect it. Leave a .25″ border of the laminate around the

edge of the label. Use double-sided tape or poster tape on the back of the label to secure it to the enclosure. Cut out the holes in the label using an X-acto™knife. Use the holes to align the label on the enclosure. Burnish the laminate label edges and the poster tape to the enclosure.

The Gerber files for a two-sided PCB layout (**Figure 7**) are available at the article link. For the build, point-to-point wiring was used on a prototype board from RadioShack, cut to the desired size to fit in the enclosure. The components were laid out and positioned the same as on the PCB layout in **Figure 8**. After wiring and testing the

#	QTY	PART REF	DESCRIPTION
1	2	R1, R7	1 meg resistor 5%, YAGEO, Digi-Key (DK) 1.0MΩBK-ND or equiv.
2	2	R13, R14	1.0K resistor 5%, YAGEO, DK 1.0KΩBK-ND or equiv.
3	2	R15, R16	20K resistor 5%, YAGEO, DK 20KΩBK-ND or equiv.
4	1	R17	470 ohm resistor 5%, YAGEO, DK 470ΩBK-ND or equiv.
5	2	R2, R8	9.00M resistor 1%, metal film, YAGEO, DK 9.00MXBK-ND, or equiv. 9.09M resistor 1%, metal film, YAGEO, DK 9.09MXBK-ND, or Vishay PPCHF9.09MCT-ND or equiv.
6	2	R3, R9	900K resistor 1%, metal film, YAGEO, DK 900KXBK-ND or equiv. 909K resistor 1%, metal film, YAGEO, DK 909KXBK-ND or equiv.
7	2	R4, R10	90.0K resistor 1%, metal film, YAGEO, DK 90.0KXBK-ND or equiv. 90.9K resistor 1%, metal film, YAGEO, DK 90.9KXBK-ND or equiv.
8	2	R5, R11	10K resistor 1%, metal film, YAGEO, DK 10.0KXBK-ND or equiv.
9	2	R6, R12	100 resistor 1%, metal film, YAGEO, DK 100XBK-ND or equiv. (Only used with 9.09M multiple resistor pairs, jumper with 10M.)
10	1	C1	10 µF metalized poly, ±10%, Panasonic ECQ-V1H103JL, DK P4513-ND or equiv.
11	6	C2	100 µF metalized poly, ±10%, Panasonic ECQ-V1H104JL, DK P4525-ND or equiv.
12	2	D5, D8	LED, GRN (green), Lite-On LTL-4232N or equiv., DK 160-1083-ND.
13	1	S1	SPDT slide switch, TE Connectivity, DK 450-1609-ND.
14	2	J1, J2	RCA chassis mount phone jack, DK CP-1412-ND.
15	1	J3	1/8" (3.5 mm) stereo chassis jack, DK CP1-3533-ND.
16	1	U1	MCP6024-I/P quad op-amp or equiv., DK MCP6024-I/P-ND.
17	1	PCB	Printed circuit board, FR-4, two-sided, 2 oz copper (final), per Gerber files.
18	1		Enclosure, SERPAC 032-B, Mouser 635-032-B.
19	1		3xAAA battery holder, Keystone 2480, DK 36-2480-ND or equiv.
20	2		BNC female to RCA plug adapter, MCM Part # 27-10030.
21	1		Velleman oscilloscope probe SA (PROBE60S) MCM part # 72-6514.
22	2		Universal DVM test lead kit, MCM Part # 21-550.

PARTS LIST
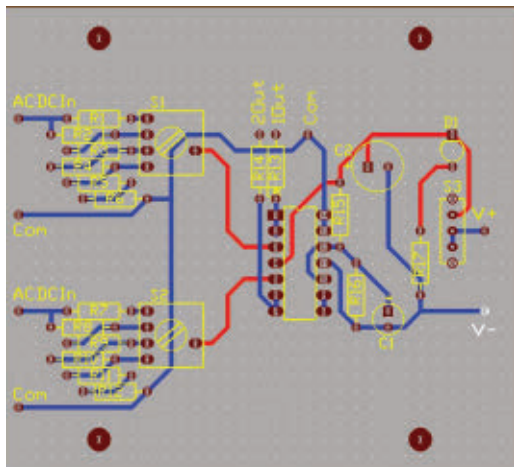
■ FIGURE 7.

**■ FIGURE 9.
Assembled
unit.**
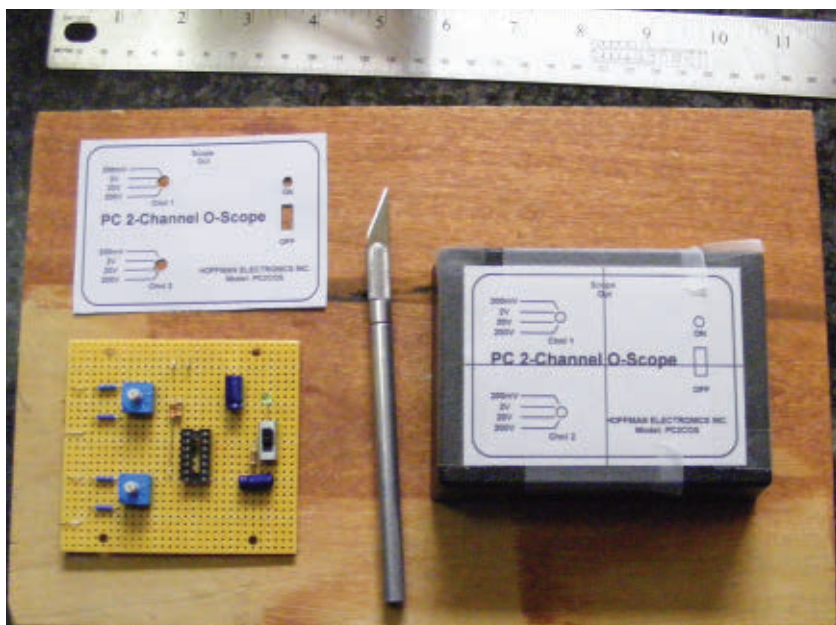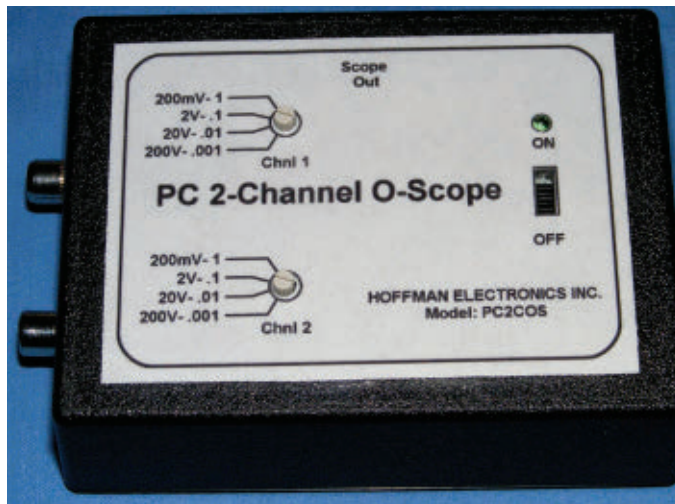
■ FIGURE 8.
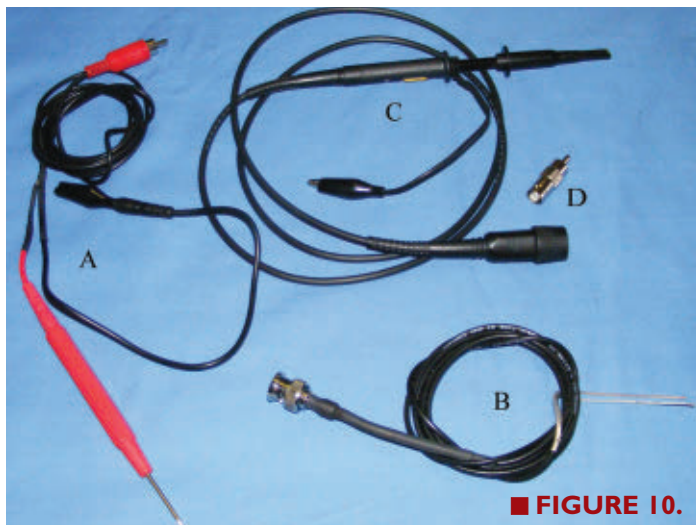
■ FIGURE 10.

circuit board, the jacks were installed into the enclosure and then wires were connected from the board to the jacks. The assembled unit is shown in **Figure 9**.

Though commercial oscilloscope probes can be used with the PC o-scope, I thought it would be nice to have some rugged customized probes more suited to automotive and project testing. **Figure 10** shows some of my homebrew and commercial probes.

First, I wanted to be able to connect them to test points that may be a few feet apart. Second, it was desirable to connect different types of probe attachments to the probe ends. What was chosen were multimeter probe leads that would allow for attaching a test probe, alligator clip, or spring-hook probe ends (**Figure 10A**).

To minimize noise, coaxial cable was used for the signal. The ground shield end had a multimeter test lead end soldered to it that allows for extended test hook-ups and attaching a probe, alligator clip, or spring-hook probe end.

Figure 10B shows a cable with a BNC connector on one end and the other end stripped and tinned to be connected to either probes, alligator clips, or spring-hook connectors. **Figure 10C** shows a commercial oscilloscope probe with a BNC connector. **Figure 10D** shows a BNC to RCA adapter used to transition the commercial probe, or the probe in **Figure 10C** to the PC scope unit.

Using the PC O-Scope

Using the PC o-scope is very straightforward. Refer to **Figure 11** for the following discussion. Connect the output of the PC o-scope (the 1/8" stereo jack) to the microphone input jack of your laptop, desktop, or tablet computer (**Figure 11B**).
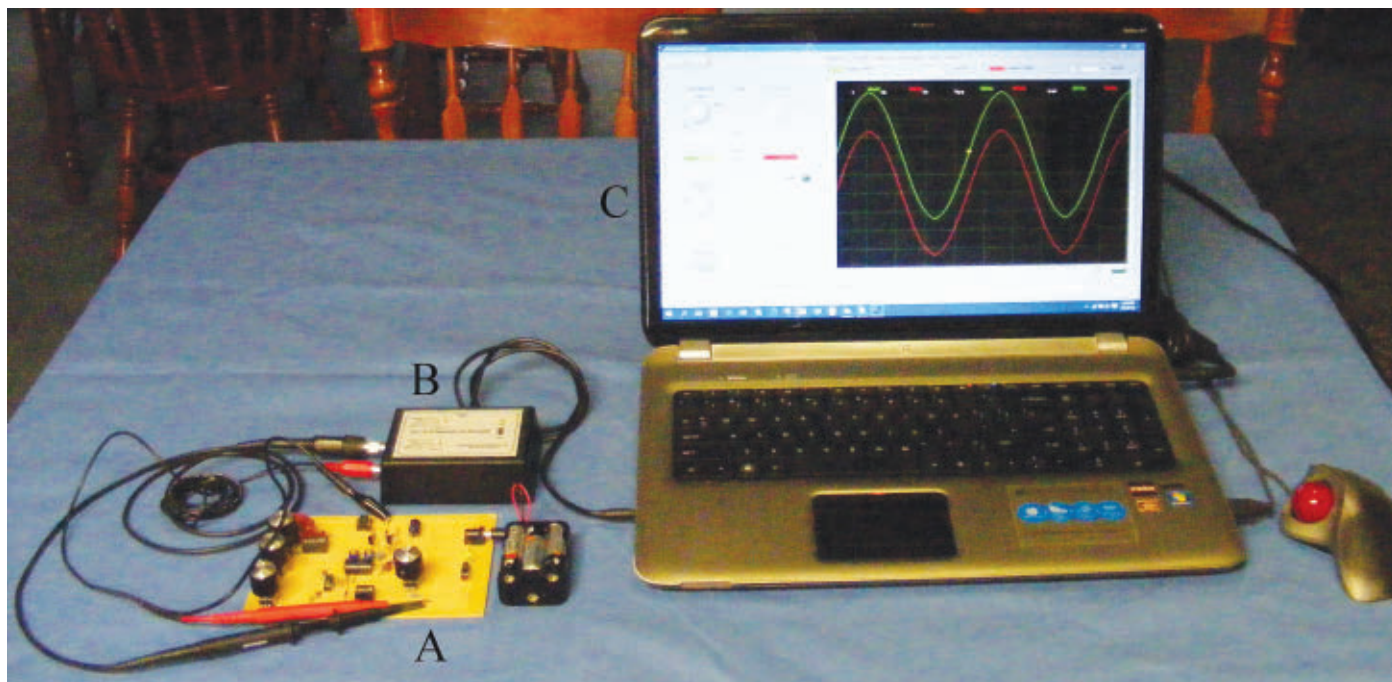
■ **FIGURE 11.**

Make sure you have installed the Soundcard Scope Version 1.46 on your computer (**www.zeitnitz.eu/scope_en**; click on scope 1.46) and then open it. Next, connect the desired scope probes to the inputs of the PC two-channel o-scope.

I connected the probes to my homebrew function generator (**Figure 11A**). Turn on the PC o-scope and the function generator. Adjust the function generator to 1,000 Hz, set the PC o-scope channel 1 and channel 2 input selector switches to the 2V-X.1 position. On your computer oscilloscope display (**Figure 11C**), set the amplitude CH1 to 100 mV/Div, click the sync box between CH1 and CH2, set the Time/Div to 2 mSec/Div, and set the trigger to auto, rising, channel 1, threshold = 120m. The screen should appear as seen in **Figure 12**.

If you click on the settings tab, then on the save settings button, you can save the Soundcard Scope settings as an .XML file to easily restore them for future use. Give them a name related to the task that they were used to perform; for example, Fnctn Gen 1.

That pretty much wraps it up. **Figure 13** shows a Lissajous figure made by 60 Hz AC line noise in channel 1 and a 120 Hz sine wave from the function generator in channel 2. A Lissajous figure is basically an X-Y plot of the signals in the CH1 and CH2 inputs.

Another interesting thing is to click on the frequency tab and explore the different frequency domain representations of a sine, triangle, or square wave. The descending amplitude peaks of the frequency multiples indicate the mix of different sinusoidal frequencies and amplitudes that would need to be added together to produce the waveform, like a triangle or square wave.
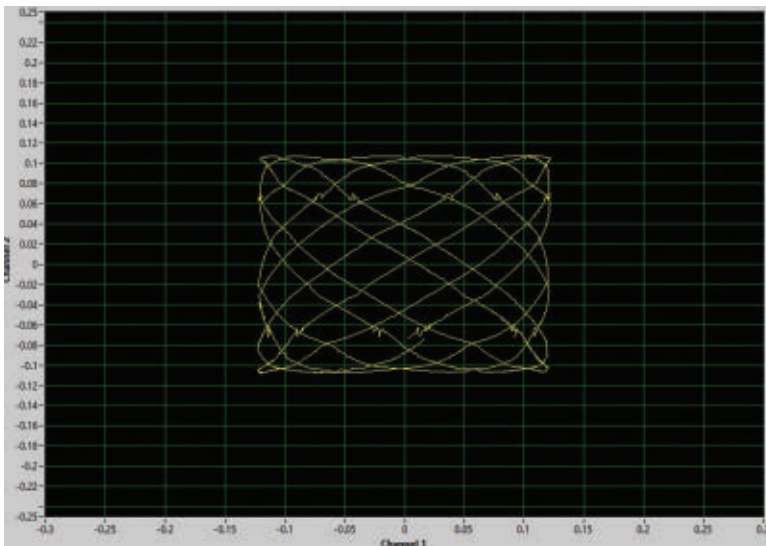
Figure 14A shows a 1 kHz square wave and **Figure 14B** shows the FFT plot of the harmonic sine wave amplitudes. **Figure 15A** shows a 1 kHz triangle wave and **Figure 15B** shows the FFT plot of the harmonic sine wave amplitudes. Notice the frequencies and amplitudes of the FFT representations. Both waves have odd number multiples of the fundamental frequency. The square wave has much higher harmonic amplitudes and shows THD at 48.43%, whereas the triangle wave has much lower harmonic amplitudes and a THD of 12.53%.

This demonstrates how the more a waveform deviates from a pure sinusoidal shape, the higher the

■ **FIGURE 13. Lissajous figure (X-Y plot).**
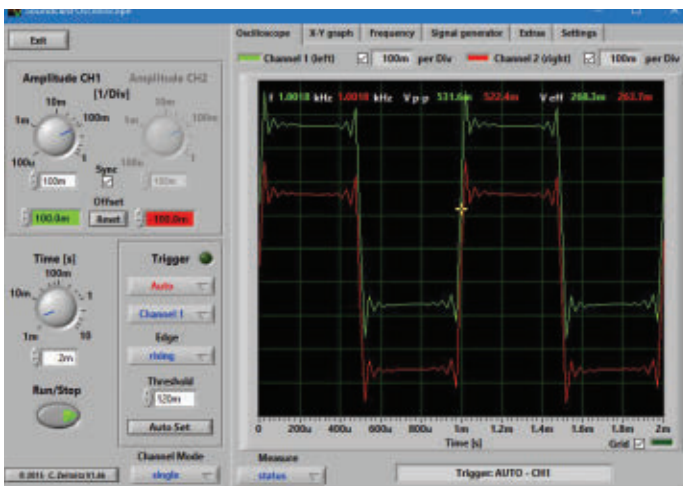
■ **FIGURE 14A. 1 kHz square wave.**
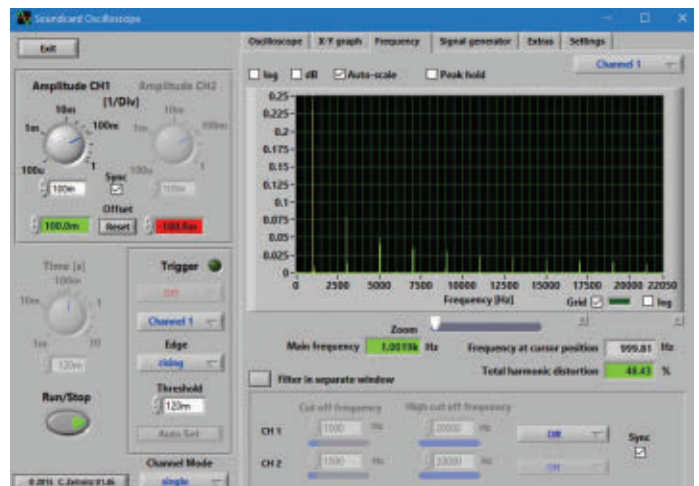
■ **FIGURE 14B. 1 kHz square wave FFT plot of harmonic sine wave amplitudes.**
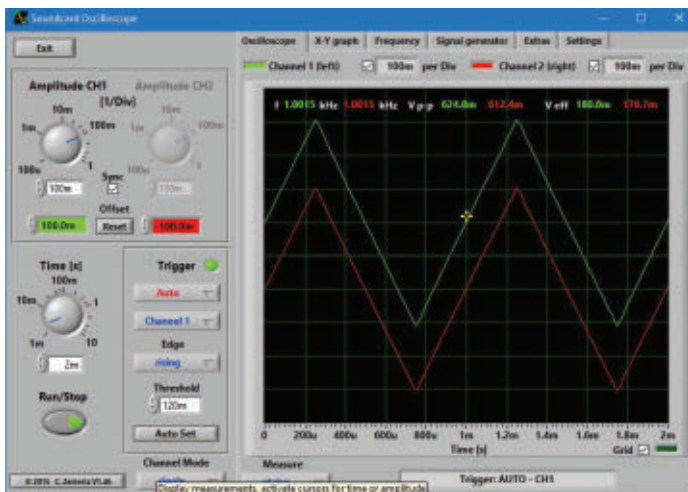
■ **FIGURE 15A. 1 kHz triangle wave.**
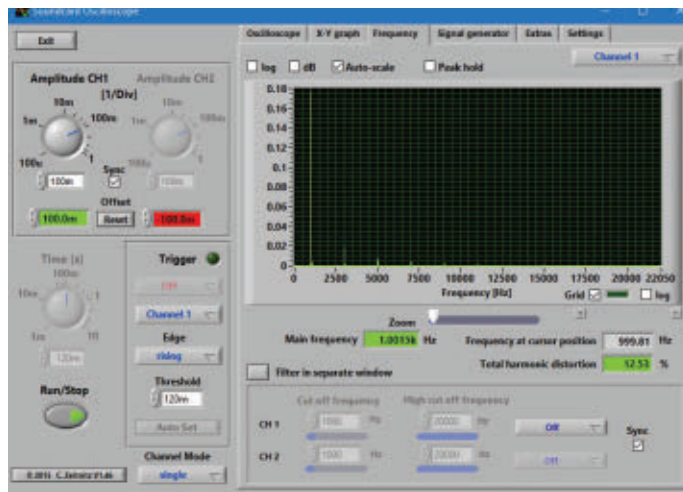
■ **FIGURE 15B. 1 kHz triangle wave FFT plot of harmonic sine wave amplitudes.**

THD and harmonic frequency content. This is why fuzz boxes for guitars drown out the accompanying vocals and other instruments.

I hope you have fun building and using your PC two-channel o-scope. It comes in handy without much cost.
NV

Resource
Oscilloscope Software:
www.zeitnitz.eu/scope_en

By Theron Wierenga
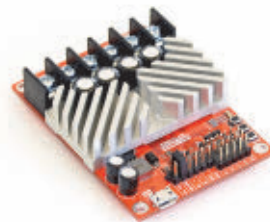
A Router
RESTARTER

Or, How to Turn On or Off Two AC Devices Whenever You Want

How's that for a long title? This device really is a universal on-off machine and not just a router restarter. It can be programmed to function in many ways. This project came about because we have a place in Florida to save us from the Michigan winters. While we are not there through the summer months and into the fall, we run the air conditioning to keep the humidity down and prevent "black mold" and other unwanted damage. I installed a smart thermostat that connects to our wireless router so I can check the temperature and humidity in Florida, as well as change settings from my smartphone. The problem I have is that over a period of several months, the router is sure to freeze up and thus need a simple unplug, then plug back in to restart. In the past, this entailed having to call a neighbor and ask them to go over and restart the router.
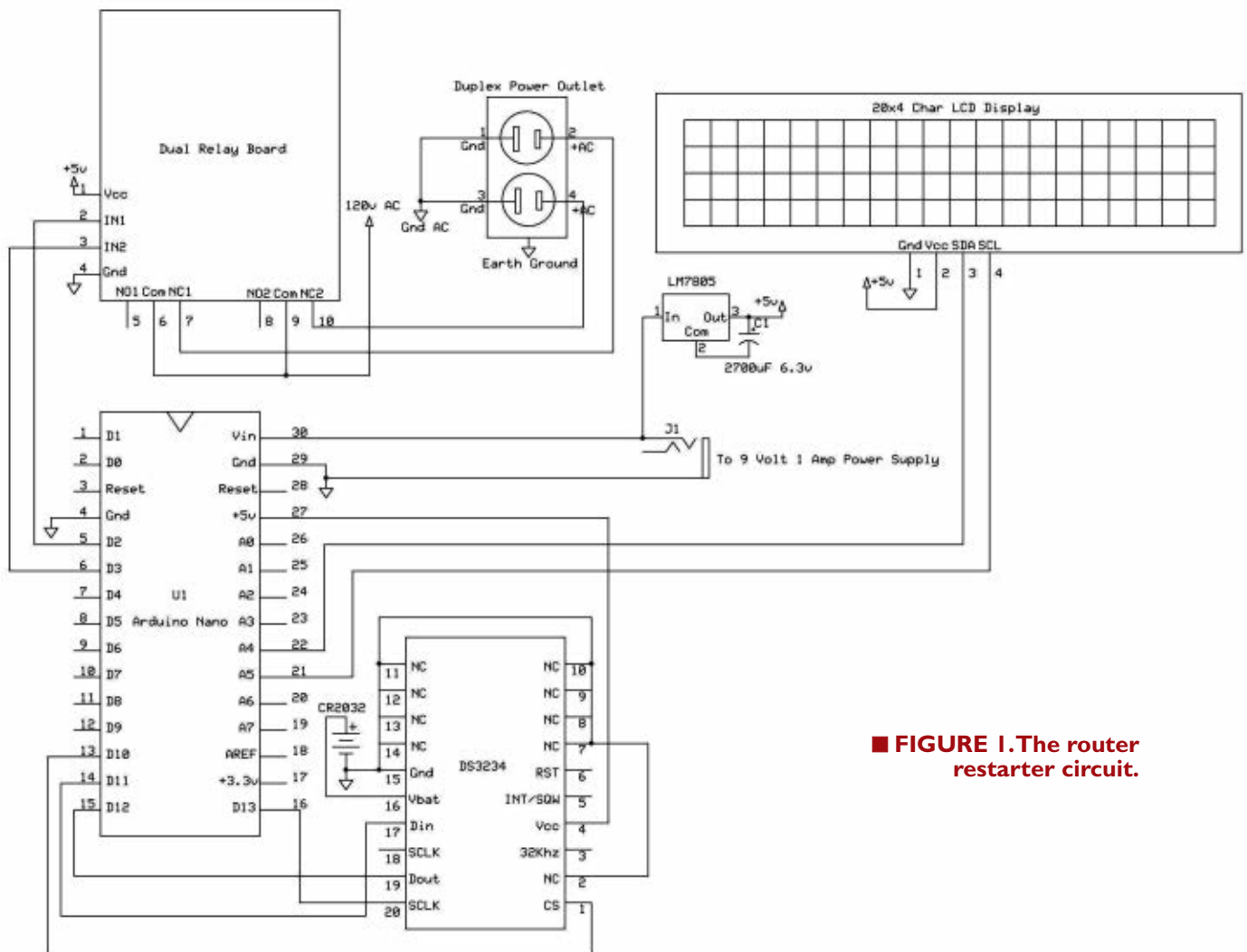
■ **FIGURE 1. The router restarter circuit.**

After noticing a dual relay board on Amazon that would work with an Arduino microcontroller, I came up with the idea of having an RTC (real time clock) connected to an Arduino that would activate a relay that turns off the AC power to the router for a brief period of time.

After a little work on scratch paper, I came up with the circuit shown in **Figure 1**. The LCD display was added as an afterthought when I discovered it would fit with everything else in the 158 mm x 90 mm x 60 mm (roughly 6 x 3-1/2 x 2 -/8 inch) plastic box which I had available.

I chose an Arduino Nano — perhaps my favorite model — as it has most of the features of the Uno but in a smaller package. In

■ **FIGURE 2. The LCD display mounted in the cover of the box.**
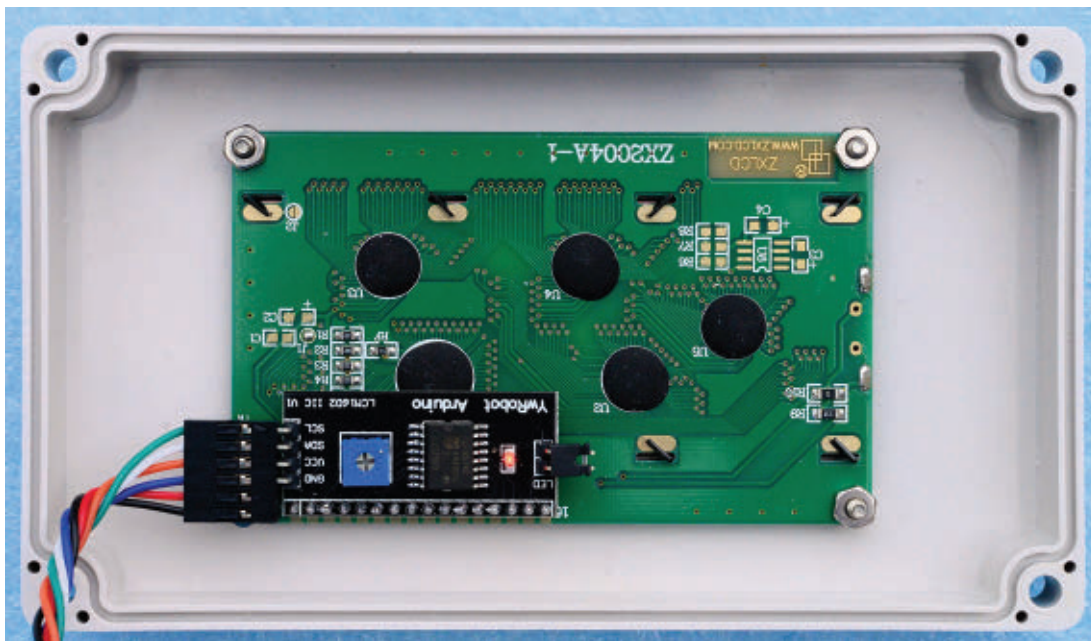
■ **FIGURE 3. The LCD display mounted in the cover.**

The dual relay board's output contacts are SPDT, so they can be wired up to turn on or turn off a device. The NC (normally closed) contacts were used, but the NO (normally open) contacts could be employed as well to control just about anything that uses 120 volts AC, up to 10 amps.

The software for the device simply turns off the channel 1 relay for one minute at 3:00 a.m. and then turns off the channel 2 relay for one minute at 3:02 a.m. With minor changes in the software and connecting to the NO contacts on the relays, it could be programmed to turn on and off lights or a coffee maker or whatever at different times.

addition, it sometimes works better not to have to build a shield to attach to the Arduino. The Nano, a DS3234 RTC chip, the holder for a CR2032 backup battery for the RTC, an LM7805 five volt regulator, and the two needed four-pin headers are all placed on a breadboard with point-to-point wiring. The DS3234 SMT circuit was mounted on a SchmartBoard SMT to DIP adapter, so it would fit the 0.1 inch pin spacing on the breadboard.

For powering the circuitry, a power jack was installed on the plastic box for a nine volt/one amp "wall wart" power supply. The plastic box also mounts a standard duplex 120 volt wall jack to plug in the things needing to be controlled (I chose the type that has a rectangular shape) and a male three-pin panel mounting power inlet socket (like those found on the back of desktop computers).

The power inlet socket takes a standard computer power cord. Along with the breadboard (inside the box) are the dual relay board and a 20-character by four-line LCD display.

Construction

If you would like to make life easier for yourself, you should consider using a slightly larger box. Everything will fit in a 158 x 90 x 60 mm version, but it is a tight fit. Start by cutting the holes you need to fit the duplex 120 volt wall jack, the three-pin power inlet socket, the round 3.5 mm power jack to mate with your nine volt wall wart, and the rectangular hole and screw holes for the LCD display.

I like to use a drawing program like Visio to create the pattern for the cutouts. For example, with the LCD mounted in the cover of the box, simply draw a rectangle the size of the box cover, a centered rectangle where the LCD will mount, and the four screw holes. When this simple layout is printed to scale, cut out the rectangle the size of the box and tape it to the top of the box. When the rectangular hole is cut and screw holes drilled

Arduino Nano
Arduino Compatible Dual Relay Board
20-Character x Four-Line LCD Display with I²C Interface
DS3234 Real Time Clock, mounted on SchmartBoard SMT to DIP Adapter
CR2032 Battery and Holder
LM7805 Five Volt Regulator with Mini Heatsink
2700 µF Electrolytic Capacitor, 6.3 volt Rating
Duplex 120 volt Wall Jack
Three-Pin Power Inlet Socket and Mating Computer Power Cord
3.5 mm Power Jack, Compatible with nine volt/one amp Wall Wart Power Supply
158 mm x 90 mm x 60 mm Plastic Case or Larger
Breadboard with 0.1 inch Pin Spacing, Cut to Size
Miscellaneous Hookup Wire, Spade Connectors, Header Pins, Six inch Four-pin Header Jumper Cables, Screws, Nuts

PARTS LIST

following the pattern, they will be nicely centered.

You could easily omit the three-pin power inlet socket and just run an AC cord into the box. The LCD display could also be eliminated, but it does provide a nice way to check on the Arduino, the RTC output, and when the relays function.

By cutting down from the top edge of the bottom section of the box for the 120 volt duplex wall jack and the three-pin power inlet socket, it made it quite easy to produce the openings; you are only cutting out three sides of a rectangular opening.

Be sure to leave space to mount the breadboard with its components, and have reasonable clearance for the 120 volt wires that connect power to the relays and the duplex wall jack.

The most time is spent doing the point-to-point wiring on the breadboard. For this, I like to have a printout of the schematic. As I add a connection or wire to the circuit, I use a red marker on the schematic to record what has been finished.

Both the dual relay board and the LCD display have four-pin headers for connections. Use short pre-made four-pin jumper cables to easily connect these to the two four-pin headers created on the breadboard. The CR2032 battery is a must for the RTC. Once programmed, this allows you to disconnect the power and reconnect it later, with the backup battery supplying the power to the RTC and maintaining the time.

Surface-Mount Soldering

The DS3234 integrated circuit only comes in a surface-mount package (an SOIC-20). This means the pins are spaced on .05 inch centers. A SchmartBoard SMT to DIP adapter is a small printed circuit board (PCB) with standard 0.1 inch spaced pins that you solder the SOIC-20 package on. With some care and forethought, it is actually not too difficult to solder the DS3234 to the SchmartBoard by hand.

Here is my method. First, using the smallest soldering tip you have available, place the smallest amount of solder
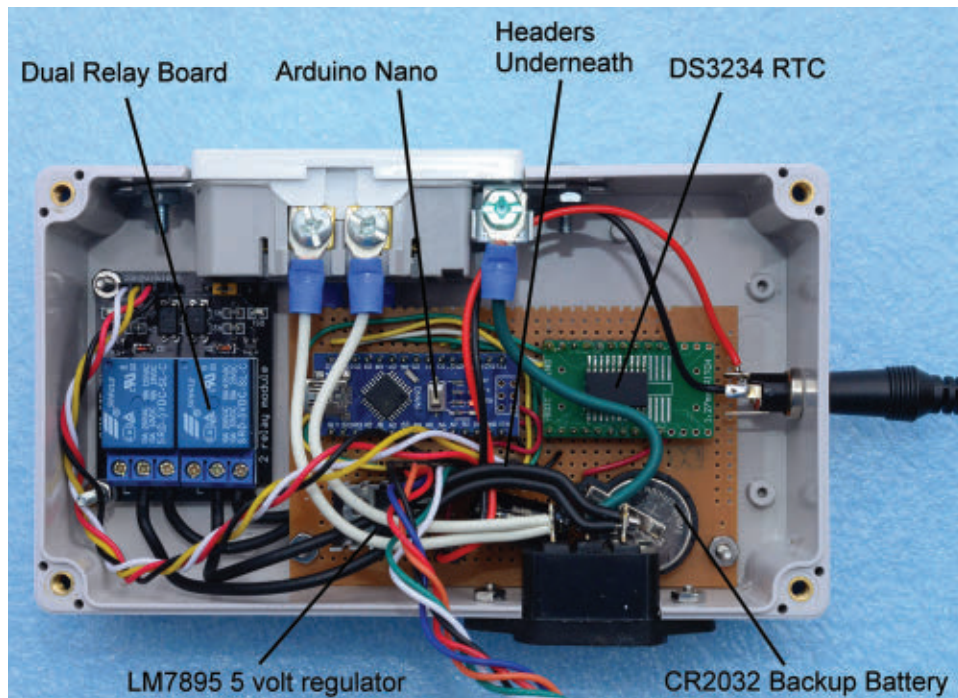
■ FIGURE 4. Interior of the box showing parts placement.

■ FIGURE 5. Side view of the three-pin power inlet socket.

■ FIGURE 6. Side view of the duplex 120 volt wall jack.

possible on diagonally opposed corners of the SOIC-20 pads on the SchmartBoard. Using a toothpick (it is also insulated against static) to help place the IC perfectly centered on the pads, press one corner pad down with the soldering iron tip, melting the small solder dot underneath. Do not go on until this first pin is soldered

down, which holds the IC in place and ensures that all other pins on the IC are perfectly placed over their pads. If the IC is not perfectly centered over all the pads, melt the solder by placing the tip of the soldering iron on the pin, and reposition it.

Next, press the pin down on the diagonally opposite corner, melting the solder under the pad. The IC is now held firmly in place and should be perfectly aligned.

Next, apply the smallest amount of solder possible to the top of each pin, without bothering to see if the solder joint is perfect. The smallest amount of solder will do. Often, it is all right to go on to the next pin without adding solder; touching it with the soldering iron tip will deposit a small amount of solder still adhering to the tip.

With a small amount of solder on each pin top, go back and slowly swipe each pin with the soldering iron tip, moving away from the IC body and melting the solder. If the solder bridges two pins, place the tip between the pins and pull it off with the tip.

If this happens, too much solder has been used. If extra solder accumulates on the tip, wipe the tip with a slightly wet paper towel. It is important to keep the tip clean using this method. If the circuit is not working, try going back over the IC pins with the soldering iron tip. Sometimes a pin can look well soldered, but is not, or there is a solder bridge between two pins.

Software

The Arduino software is fairly simple. The main program loop basically reads the clock and then — given the current time — checks to see if a relay needs to be turned on or off.

The SPI library is included for communication with the RTC:

```
#include <SPI.h>
```

The Wire library allows use of the I²C two-wire bus:

```
#include <Wire.h>
```

The LCD display is one of several different types available and comes with a built-in interface for I²C two-wire communication. This model used the LiquidCrystal_I2C library and compatible settings when initializing the LCD object. Be aware that these settings do vary with different LCDs:

```
#include <LiquidCrystal_I2C.h>
// Set the LCD I2C address for 20x4 LCD
LiquidCrystal_I2C lcd(0x27, 2, 1, 0, 4, 5, 6, 7,
3, POSITIVE);
```

There are three functions to simplify the use of the

LCD. They are: *Display_Time()*, *Display_Date()*, and *dateString()* — the latter to concatenate the month, day, and year into a single string.

There are also functions to initialize, set, and read the RTC. Here are their prototypes:

```
// Necessary variables
byte second, minute, hour, ampm, dayOfWeek,
dayOfMonth, month, year, f1224;

// Initialize DS3234
void RTC_init_DS3234()

// day(1-31), month(1-12), year(0-99),
// dayofweek(1-7) Sun = 1,
// ampm(0-1) 0 = am, 1 = pm, hour(0-23),
// minute(0-59),
// second(0-59), 12/24 hr, (0-1) 0 = 24 hr.,
1 = 12 hr.

// Set Time and Date info
void SetTimeDate_DS3234(byte d, byte mo, byte y,
byte dw, byte ampm, byte h, byte mi, byte s,
byte f1224)

// Read Time and Date info
void ReadTimeDate_DS3234(byte *second, byte
*minute, byte *hour, byte *ampm, byte
*dayOfWeek, byte *dayOfMonth, byte *month, byte
*year)
```

The relays are controlled by simply connecting the input pins on the relay board to digital pins on the Nano, and setting the digital pin output to HIGH to activate the relay or LOW to deactivate. These three functions handle the operation of the relays:

```
// Set Start Time
// Channel number 1-2, hour, minute, AM or PM
void setStartTime(byte chan, byte h, byte m,
byte apm)

// Set End Time
void setEndTime(byte chan, byte h, byte m, byte
apm)

// check Time
void checkTime()
```

setStartTime sets the channel number (the relay to be used) and the time to activate it. *setEndTime* sets the channel number and the time to deactivate it. In all cases, only the hour and minutes are used. *checkTime* checks the time against set times for activating or deactivating the relays and acts if necessary.

Included in the setup block of the Arduino program are the following:

```
// Set our times on the two channels
setStartTime(CHAN1, 3, 0, AM);
setEndTime(CHAN1, 3, 1, AM);
setStartTime(CHAN2, 3, 2, AM);
setEndTime(CHAN2, 3, 3, AM);
```

The cable modem is powered by channel 1, which will be turned off at 3:00 a.m. and turned back on one minute later. The router is powered by channel 2 and is connected to the cable modem. It is turned off at 3:02 a.m. and turned on one minute later.

The complete program can be found at the article link.

Improvements

What this project doesn't have is an easy way to change the start and end times for the relays. For my project, this wasn't a problem. For

those who need to make changes, the only way is to make changes in the program and then upload the new program to the Arduino Nano.

Changes could be done with the TSOP38238 infrared receiver available from Adafruit and also their mini remote control. There would also need to be some extensive software additions to receive the various signals to change the start and end times, but this is certainly a possibility. **NV**

When programming the Arduino Nano, here's an important point not to miss. Program the Nano with the *SetTimeDate_DS3234* function in the setup block of the program. The function includes the current time and date at your location. This will set the real time clock going in the DS3234, and with the installed CR2032 backup battery, the clock will continue to run when power is removed.

Next, comment out the line with the *SetTimeDate_DS3234* function, then program the Nano again without it. Now if you remove power, the DS3234 will continue to run. When you power-up the Arduino Nano without the *SetTimeDate_DS3234* function, it will not overwrite the clock's current time. Notice also that the five volt power for the DS3234 comes from the five volt output of the Nano. This allows you to plug in your USB cord to program the Nano, plus the DS3234 will be powered as well. This is convenient for debugging as the five volt LM7805 regulator does not need to be powered.

A S☀lar Energy Story

Design, Installation, and Performance

FIGURE 1. Finished view of the solar array.

By Jack Olivieri

Post comments on this article and find any associated files and/or downloads at **www.nutsvolts.com/magazine/article/ August2016_Solar-Design-Installation-Performance.**

The Solar Revolution is here whether we like it or not. I came to this realization last year when it became apparent how many solar companies were going out of their way to annoy me by calling night and day. Even hanging up on them did not always work. They are still calling to this day ... they are a persistent bunch. If you go into a big box home improvement store, it is likely you will be met (accosted?) by them at the entrance. Ultimately, I was pulled into the fray, but not because of any altruistic desire to go green. I wanted to stop being at the mercy of my electric utility and get some "free" energy by becoming my own electric power plant. This story started during the winter of 2014-2015 and ended with a solar array on my roof (see Figure 1) and ancillary equipment in my basement.

The Beginning — Anger Management

Anger is a good motivator for some people. I am one of them. I had been trying to reduce my electricity consumption during 2014. Despite my efforts to reduce air conditioning, heating, and lighting loads, my electric bill started rising dramatically at the end of 2014 and into 2015 — sometimes exceeding $250. I had even switched to a different power generation company, which is allowed in Massachusetts. However, the reduced rate was on the "generation" part of the bill only. After the power transmission charges, distribution charges, and taxes were added, there was not much change in the bill. I decided to measure and quantify my consumption.

During the next several weeks, I graphed all the historical data I could grab to determine what I was paying per KWH (including all generation, transmission, distribution, taxes, etc.). **Figure 2** shows the results. Although the rates had been somewhat stable prior to December 2014, they began a steep increase after that, peaking at 0.25 per KWH. Since then, the rates have come back down, but not to where they were before. I wasn't sure if they would spike again, despite lower oil prices. (Massachusetts generates most of its electricity from natural gas, coal, and nuclear.)

Decision Time

Before I made a decision, I had to learn about net metering (see **sidebar**). I investigated the topic and everything still looked like a go. It was now time to make a decision, but I knew it was not going to be easy to determine if solar would be cost-effective. There are a lot of companies today with many offerings and options.

The first issue I had was which company to choose. I decided to initially limit my investigation to the top three
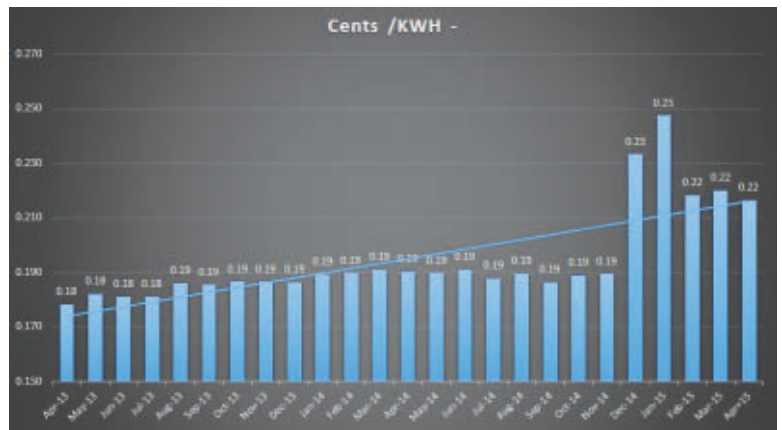
FIGURE 2. My historical electric rates.

solar companies in the US who served my area. There were some solar companies who made contact with me who only served southeastern New England, while other companies only consisted of five employees. I reasoned that if solar credits and incentives go away (always a possibility) or there is an economic downturn in the industry, the largest and most established businesses would be likely to weather it.

However, even that is no guarantee, and some large companies have recently been in the red. Federal and state tax credits are constantly expiring and changing, but are usually extended. I started with Solar City, Sunrun, and Sungevity as the three I would focus on.

Let the Games Begin

I contacted all three companies, and in short order I had several conversations with each of them. I asked a lot of questions (see the **sidebar**, Questions to Ask a Solar Installer) and got references from neighbors that had installations from each company. While I was speaking to my neighbors, the companies analyzed a recent electric bill I had sent them. They then used Google Earth to look at my house to come up with a preliminary proposal. They studied the orientation (I was 20 degrees off true south) and size of my roof, shadowing from trees and structures, and obstacles on the roof such as chimneys, vents, and antennas that needed to be avoided.

My roof was about 7-8 years old. Obviously, if a roof needs repair, the time to do it is before an array is installed. The array will actually lengthen the life of the part of the roof that it covers since degradation from sunlight and snow will be minimized. After a comparison of their proposals (which were all similar), it came down to price and contract terms. After some more negotiations, I chose Sunrun.

Contract Terms

Before the engineering could continue, I had to sign a

Net Metering

Net Metering is a service that allows a consumer to deliver excess energy from a solar photovoltaic array into the grid for credit. In effect, the grid becomes an unlimited "battery" for storage.

Each state has different laws, regulations, and allowances for net metering. In MA, a power utility must provide a one-for-one credit for each kilowatt hour produced (KWH). However, the utility only has to provide net metering to its customers up to a percentage of the utility's generating capacity. Once, that threshold (cap) is reached, the utility is not required to offer net metering (unless the law increases the cap).

Also, there may be a limit to the size of the customer's array (10 KW in MA). If the customer has a muncipal owned utility, net metering may not be available or only available for purchased systems. Net metering is vital to making solar economically justifiable for the homeowner, so it is critical to learn all the details. The solar companies should know exactly what the rules are for your area.

Questions to Ask a Solar Installer

1. Has your solar company installed any systems in my town? Or a nearby town? Could I get their names and phone numbers to discuss their experience? How many systems in my state are installed?

2. Will the solar company perform its obligations during the entire initial term (20 yrs) even though the solar facility may not be "economically viable" as sometimes stated?

3. When does the site visit/audit take place?

4. How long after the site audit will it take for the design to be completed?

5. If my roof needs repair, how much will it cost to remove the system and re-install it?

6. Are the inverters used string inverters or microinverters or power optimizers? Why do you use that particular method?

7. Must I carry insurance that covers damage to my home caused by the system? What examples are there of how the solar facility could damage my home?

a. Is damage to the system covered by insurance carried by the company (if I lease or buy)?

8. What is the cost for power (in $/KWH)? Is there a chart that shows the yearly cost for electricity? Is it fixed or variable?

a. Does it go up due to slight degradation in the solar panels?

b. Is it the same if I buy or lease?

c. Can I pre-pay the monthly payment if I lease?

9. If my roof needs extra bracing to hold the solar facility, am I responsible for that work?

10. What is the lead time for installation of a system right now?

11. What is the warranty on panels and the inverter if I buy the system? What is the warranty if I lease?

12. If I lease, is there an option to buy?

13. What is the performance guarantee and when is it paid out? Is it the same if I buy or lease?

14. How is maintenance covered if I buy the system? Is there a site visit charge?

15. Is there financing available if I buy?

16. Do I have to approve the final design before the deal is consummated?

17. What is the warranty on roof leaks caused by the system?

Resources

Buyer's Guide to Solar Financing
www.kaplancleantech.com/resources/solar/a-buyers-guide-to-residential-solar-financing

Inverter Types
www.solaredge.us/groups/us/technology/microinverters
www.energysage.com/solar/101/string-inverters-microinverters-power-optimizers
www.pv-magazine.com/archive/articles/beitrag/microinverters-vs-optimizers-_100016637/618/#axzz41f5JkzP8

Heated Blog about the Best Inverters
http://energyinformative.org/are-solar-micro-inverters-better-than-central-inverters

Roof Rake
www.roofrake.com/Productpages/snowpro2.asp

Federal Tax Credits
http://solaroutreach.org/wp-content/uploads/2015/03/ResidentialITC_Factsheet_Final.pdf

Solar Payback Calculator
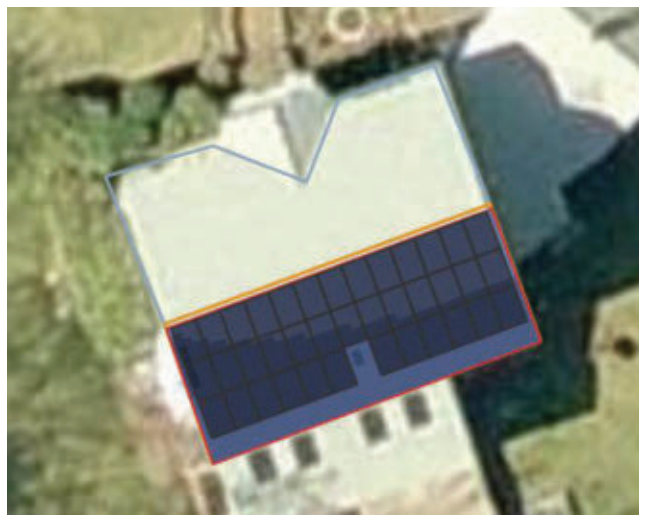www.sunearthtools.com/solar/payback-photovoltaic.php#top

contract. The big issue was whether to buy vs. lease. Buying the system seemed attractive to me at first. Two of my co-workers (who chose different companies) decided that buying was best for them. The more I investigated, the more I was not sure it was right for me (see **Resources**). Here are the pros and cons for buying a typical system:

Pros:

• No payment to the solar company on a monthly basis.

• Usually maximizes financial benefit; payback is usually 7-10 years (be sure to consider array maintenance, inverter replacement, warranty extensions, and any increased homeowner insurance costs).

• You own the system; if you move, the sale price of the house includes the system.

• You own all the credits and incentives (Federal and State), and take them each year or when available. This could reduce the initial cost of the system by 50% or more. See the **sidebar** on Solar Tax Credits.

Cons:

• Large amount of money up front, either cash or financing.

• If government credits get reduced, credits may not be sufficient to recoup expenses as quickly.

• Maintenance is homeowner's responsibility (or may be $500 a visit quoted by one company).

• Property insurance on the solar array is homeowner's responsibility (some policies may cover it, unless it is considered "wearout").

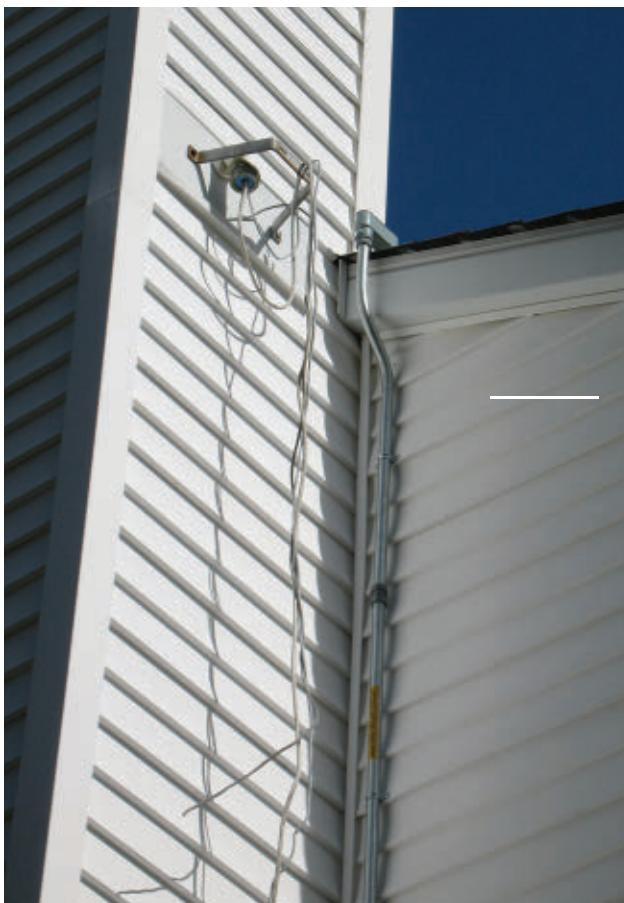• May/may not have an adequate performance guarantee.

FIGURE 3. Google Earth view of the proposed array.

Solar Tax Credits

• Depending on the state and locale, increased property taxes could result (usually not likely).

See the **Resources** section for a payback calculator. In the end, I decided on a fixed cost lease agreement. Listed below are the terms in my contract, but yours could vary widely depending on the many variables mentioned above:

1. I will pay a fixed $85/month for 20 years based on the system design (maximum rated power of 9,880 watts). This is regardless of the power produced each month.
A. Many leases include an escalation charge of 1-7%/yr. I agreed to a slightly higher monthly payment for a fixed payment for 20 years.
2. All maintenance and warranty costs for the system are the responsibility of the company.
3. No deposit or upfront costs.
4. Performance is guaranteed at approximately 10,000 KWH/year. If less is produced, I will get a check for the difference at the end of each year (less a slight degradation factor for the solar panels over time).
5. All credits and incentives go to the company.
6. The system is insured by the company, except for a baseball hitting the panels. (Whose idea was that?)
7. No property tax assessment (in MA); even if the law changes, I don't own the system.
8. The system has an option to purchase after five years based on a sliding scale.
9. Selling of the home: System must be paid off or the contract must be transferred to new owners.

These are the basics of the contract. In any event, it must be read thoroughly. I have included a list of questions to ask here. Don't be shy about this. If something is not clear, ask the question.

Engineering the Sun

Next, a site visit was planned to look at roof pitch, structural soundness, and composition (asphalt shingles).

FIGURE 4. Engineering spec drawing of the array.

FIGURE 5. Location of feed from the roof.

After the site visit, I was sent another preliminary design with more detail that is shown in **Figure 3** and **Figure 4**. The design had to be revised because a satellite dish on the roof was no longer used and two more panels could be added. In addition, the company had added a few panels to the front roof visible from the street which my spouse did not appreciate.

After some analysis, it was determined they only added 4% to the total energy output, so they were deleted. (I later wondered if the extra panels would have put me over the 10KW maximum to permit net metering in my state.) All the panels would be on the back of the house. Since the house is a two-story colonial, they would be not seen from the deck, just in the back yard some distance from the house.

It should be noted that I had to approve the final design, even though I had already signed the contract. If the numbers in the proposal changed because of the site visit or I did not approve the final design, the deal was off. A project planner was assigned to us. He was my point of contact for technical issues, including the status of permits, inspections, and approvals. I approved the final design.

The array consisted of 38 panels (REC260PE) with a nominal power output of 260 watts and 16% efficiency. The total array had a power output of 9,880 watts nominal. The panels have a 10 year product failure warranty, but the lease agreement guarantees a 20 year replacement life. They are wired in a series/parallel arrangement, and the DC voltage is fed through conduit down the side of my house (see **Figure 5**). You can barely see the conduit from the ground. It is tucked in the chimney chase corner.

A close-up is shown in **Figure 6** where the feed comes down from the roof next to an old antenna bracket and old wires. The wiring is then fed into the basement to the inverter (**Figure 7**) and interior shut-off switch (on the right). The inverter is a SolarEdge inverter (SE10000A-US) rated at 10,000 watts. There are system shut-offs both inside and outside the house. The conduit on the left side comes from the array and the conduit on the right of the inverter goes up to the meters on the outside of the house (**Figure 8**). There is a net meter supplied by the electric utility, a solar performance meter supplied by Sunrun, and an exterior shut-off.

Microinverters vs. String Inverters vs. Power Optimizers

Recently, there has been a lot of discussion on processing solar power and the best architecture for a solar photovoltaic system. Here is a short summary of three different methods:

1. Sunrun used power optimizers on my system which had a small module on each panel to condition the DC before sending it to the centrally located inverter in my basement, where it is converted to AC and synchronized to the power line. The only downside I have found with this arrangement is fan noise. There

FIGURE 6. Close-up of feed from the roof.

are two fans in the inverter that turn on when the inverter is converting significant amounts of power (>4,000 watts), which is typically in the middle of the day. If there is a 2% inefficiency, the inverter has to get rid of 200 watts. The metal case gets warm on the sides and top. Would an external heatsink keep the fans from coming on? I have not tried that because the two small fans do not make that much noise and have not really bothered me (yet).

2. Underline String inverters have the panels organized into groups or strings, and work best with all the panels on the same plane with no shading. (This was not my situation.) If one panel in the string is shaded, the output drops for that string.

3. Underline Microinverters convert the DC to AC right at the panel before sending the power down to the basement; there is no need for a central inverter. They also tolerate shading. However, microinverters are more costly, and typically have more components with lower reliability (e.g., electrolytic capacitors) and lower efficiency (96% vs. 98% for power optimizers). Also, the more electronics on your roof, the higher the temperature swings (and failure rate), and the more difficult it is to maintain them when they fail.

There are many white papers (and heated discussions) on the best inverters and solar system architecture. They can be easily found with a Google search of the topic (see **Resources**).

Installation and Operation

From the time I signed the original contract until turn-on, it took about 4-1/2 months. The actual time to install the system took less than two days. Why such a big difference? The rest of the time was spent by the company obtaining local permits, scheduling inspections, discussing issues with the power utility, answering my questions, revising the design, etc.

For example, the building inspector got into the act and made sure the brackets that hold the panels were secured into the rafters of the house and not just the plywood. Apparently, the assessors took the opportunity to tour the property when they heard the building inspector was invited.

It also took two weeks waiting for the electric utility to swap out my meter for a net meter. It literally took them 10 seconds to do the actual swap. I timed them.

FIGURE 7. Inverter and shut-off (right) in the basement.

FIGURE 8. Metering outside the house.

Monitoring

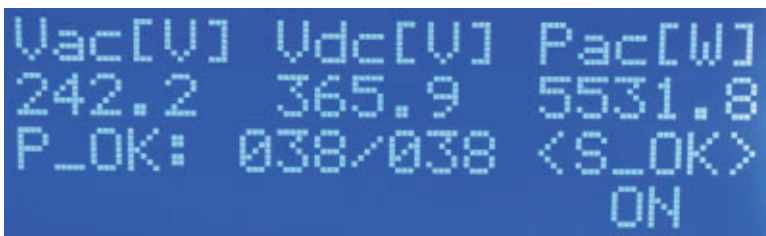The system went live on August 7, 2015. There are a few ways I can monitor the performance of my system:

```
Vac[V] Vdc[V] Pac[W]
242.2  365.9   5531.8
P_OK: 038/038 <S_OK>
                 ON
```

FIGURE 9. Voltages and power production status.


```
Vac[V] Vdc[V] Pac[W]
244.4  369.0   7919.6
Fac[Hz] OPs_Ok Temp
59.9        38   123.5
```
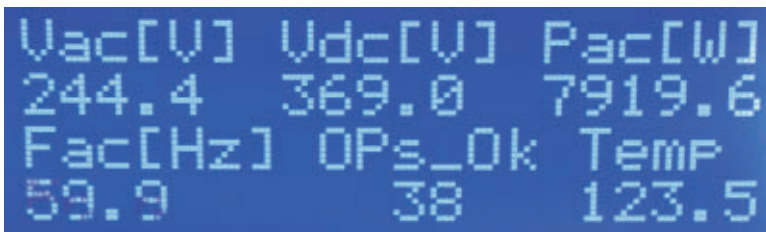
FIGURE 10. Frequency and temperature status.


```
Day[KWh]:        15.3
Month[KWh]:      342.1
Year[KWh]:       662.2
Total[MWh]:      4.315
```
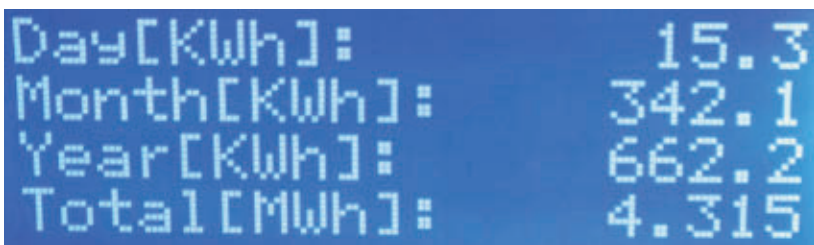
FIGURE 11. Power produced over time.

FIGURE 12. Inverter Wi-Fi antenna.

1. Manually, using meters. In the first few days, I looked at the Sunrun meter and the net meter. The meters flash different statistics based on how much power you are generating and how much you are consuming. The meters have unique IDs, show the date and time, and other useful data. After about a week, it was getting old running out to the meters at the end of the day (sometimes with a flashlight) to see the stats. The meters are the most accurate (although not the most convenient) revenue grade data available.

2. Sunrun website. Sunrun maintains a website where you can see all your data. It is very useful and shows how much power has been generated for the day, week, month, and year. It can take 24-48 hours for the data to show up, however.

3. SolarEdge inverter. There are diagnostic screens on the inverter, so naturally I had to play with them. **Figure 9** shows the AC and DC voltages produced, the power (in watts), and how many panels are operational (38 out of 38). This information is sent to the solar company for diagnostic monitoring. **Figure 10** shows the frequency of the AC voltage and the temperature of certain power components in the inverter. **Figure 11** shows the amount of power produced for the day, month, and year. So, when I am in the basement near the inverter, I check the

diagnostic screens by cycling through them. There are several other screens, including the status of the Zigbee connection to the panels.

I knew there was a Wi-Fi antenna on the inverter (see **Figure 12**), so I contacted the inverter company to see how I could log into it. After several attempts, I was told that the installer (Sunrun) had to register me for that. After a total of 3-4 weeks back and forth, I was successful. I could log into a SolarEdge website where the data was presented near real time (within five minutes). This is the primary method I use now from work or anywhere else. I am planning to try it from a cruise ship this summer if the connection is fast enough. There is a SolarEdge app on my smartphone which works well also.

Performance and Results

The results shown are based on the SolarEdge website and my own utility records. **Figure 13** shows the performance by month of the system. December was the poorest month due to shorter days and cloudy skies. However, February was on track to become even worse because of snow. **Figure 14** tells the story. At the top is the summary statistics as of February 28. There was a 10" snowfall on Friday, February 5. It was a heavy wet snow. I had bought a soft roof rake (see **Resources**), but by the
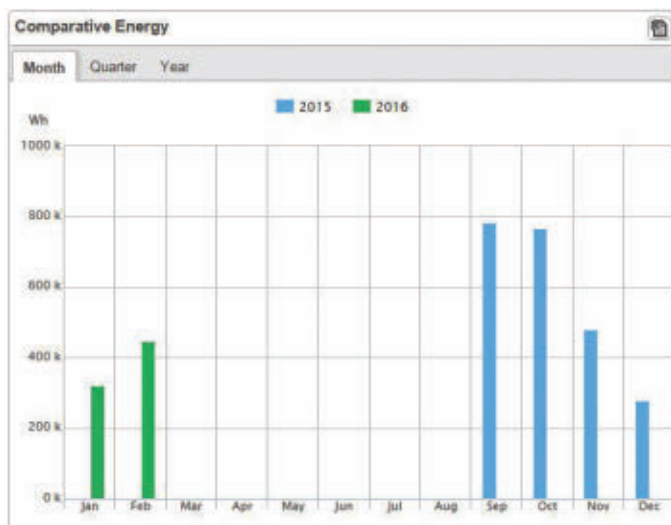
FIGURE 13. Power produced by month.

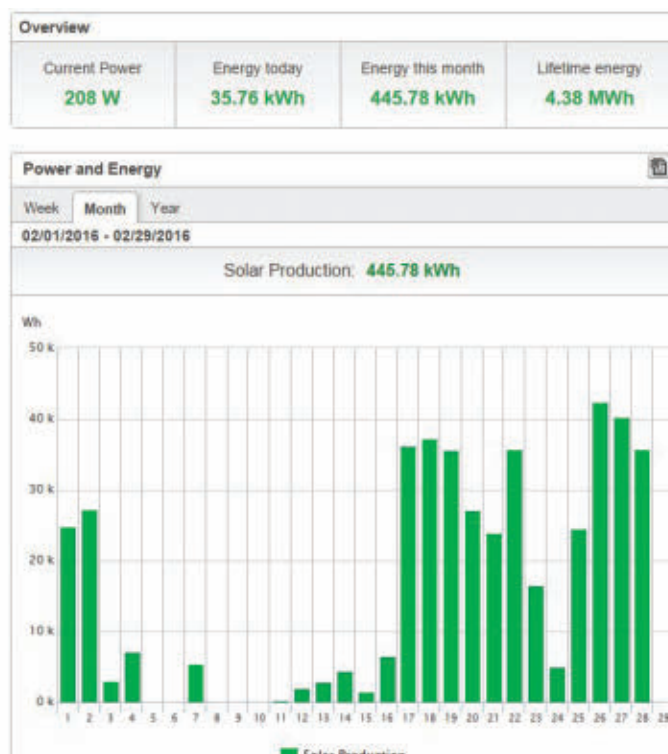**FIGURE 14. Power produced in February 2016.**

time I got up on the lower porch roof, the snow had crusted over and it wasn't going anywhere. It is important to use a roof rake made for this purpose, so you don't scratch the panels. If the snow was soft and fluffy, I think I could have moved it.

On Sunday (the 7th), it started to melt slightly and the sky got brighter. Unfortunately, the following day (the 8th) we got hit again with another five inches of snow; the panels did not start to clear until the 11th. During most of this time, there were sub freezing temperatures. Gradually, production increased each day until it was about 35 KWH on the 17th (it rained the day before and that got rid of the remaining snow). So, snow can really make a difference.

If the snow completely covers the array, the array will not warm up and melt the snow. **Figure 15** shows the snow just starting to clear on the right side of the array partly due to my heroic (but feeble) attempts to clear it. When production resumed, it was even possible to see a plot of the power produced for a single day (**Figure 16**).

During these snow and subsequent wind storms, we did not lose power but some of the neighbors did. When the power is lost to a home, the solar photovoltaic system automatically disconnects from the grid as a safety precaution. If the utility company is working on the wires, the last thing they want to encounter is an unexpected live wire coming from a home.

So, if you want backup power during an outage, you will still need a generator.

Rain and Snowmarmageddon

I learned that even on a rainy day, production can be 3-7 KWH. A cloudy day (depending on how cloudy) can result in 5-15 KWH of production. Snow (>1 inch) pretty much shuts down production. Last year, we got buried in snow and broke all kinds of records in New England; it would not have been a good winter for solar energy. How fast the snow clears off the panels depends on the temperature, type of snow, depth, and roof pitch.

FIGURE 15. Snow covering the array.

FIGURE 16. Power production during the day.

I have roughly a four inch 12 pitch roof which means there is a four inch rise for a 12 inch run, or about 18-20 degrees. For snow to fall off faster, a 35 degree pitch is recommended. When the snow falls off solar panels, you can really hear it. When it hits my cellar bulkhead, you would think a train is rumbling next to you or you are experiencing a small earthquake.

Make sure you do not have anything delicate or fragile underneath the array.

Savings

So, how much am I saving? Was it worth it? **Figure 17** shows the KWH billed by the utility company after the system was installed compared to the same month during the previous year. September 2014 was an anomaly. I used a tremendous amount of power to dry out my cellar after a water leak flooded everything. That, hopefully, was a one time event. Still, there were two months where I generated more power than I used.

It was nice to get a bill from the utility for $0.10 one

month and a credit for $0.18 the next. Of course, I still had to pay Sunrun the monthly fee.

Figure 18 shows my overall total cost for electricity in dollars, including the utility cost and the Sunrun payment. Every month was less than the year before. **Figure 19** shows my savings in percentage by month. Discounting September 2014, my average savings is about 32% per month so far.

While some of these savings may be due to my modest efforts at energy conservation, I am expecting higher savings during the spring and summer months.

So far, I am below the performance guarantee. I should get closer or meet it during the rest of the year. Stay tuned!

Summary

Overall, I am very happy with the system. I would do it again, since it has saved me significant money on my electric bill. The Sunrun folks were very consistent and professional in their approach and answered all my questions.

One caveat, though. When many people get solar, they increase their consumption because they figure they have a free source of energy.

To save money, it is still necessary to focus on conservation. I am continuing to convert my fluorescent lights (and CFLs) to LEDs and turning off unnecessary loads.

Whether you lease or buy a system, it is a rewarding feeling to be getting something for free. **NV**
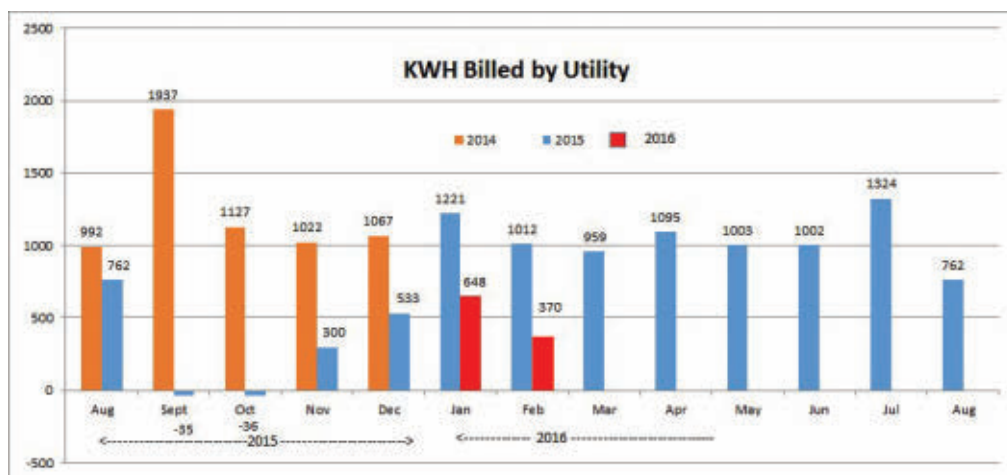
FIGURE 17. The KWH/month billed by the utility.
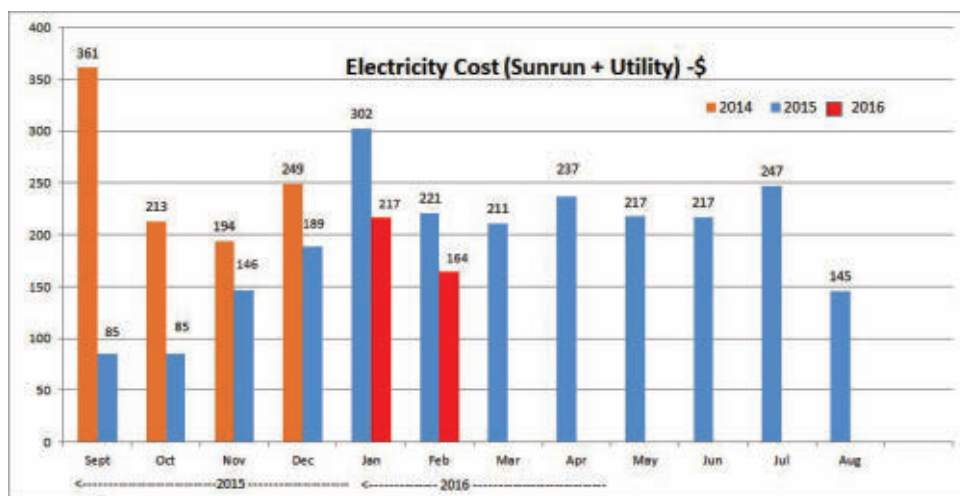
FIGURE 18. Total cost per month.
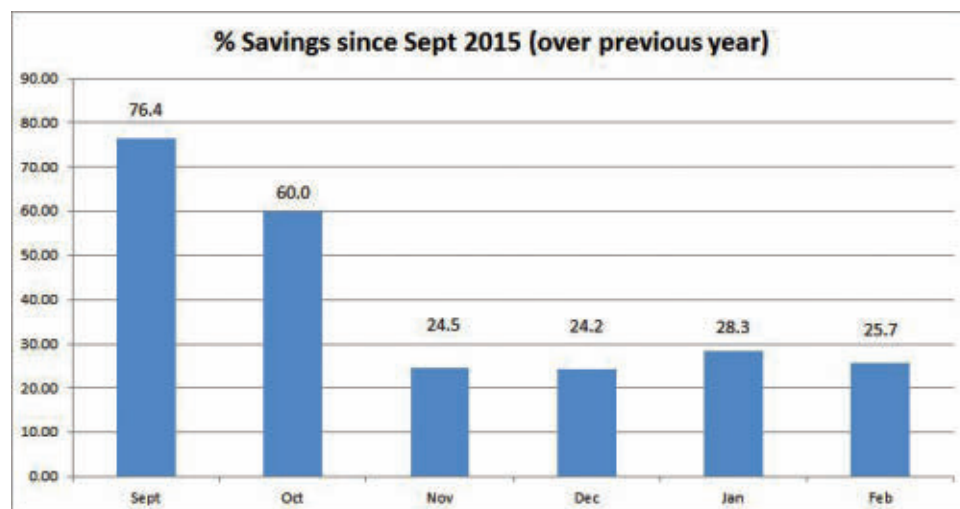
FIGURE 19. Percent savings per month.

GREAT FOR DIYers!

Raspberry Pi Electronics Projects for the Evil Genius
by Donald Norris

This fully illustrated TAB guide shows how to construct and program all kinds of fun and innovative gadgets with your Raspberry Pi. *Raspberry Pi E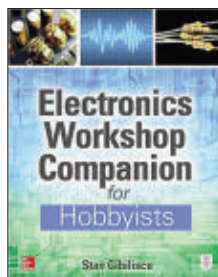lectronics Projects for the Evil Genius* features 10 complete projects that showcase cool RasPi applications in computing, communications, robotics, photography, and video. Each inexpensive project includes a detailed list of materials, sources for parts, schematics, and clear step-by-step assembly and programming instructions.
$25.00

Electronics Workshop Companion for Hobbyists
by Stan Gibilisco

In this practical guide, electronics expert Stan Gibilisco shows you, step by step, how to set up a home workshop so you can invent, design, build, test, and repair electronic circuits and gadgets. Electronics Workshop Companion for Hobbyists provides tips for constructing your workbench and stocking it with the tools, components, and test equipment you'll need. Clear illustrations and interesting do-it-yourself experiments are included throughout this hands-on resource.
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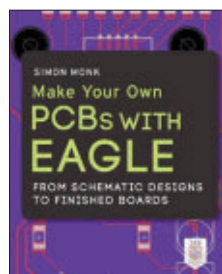
$30.00

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by Donald Norris

**Learn To Easily Create Robotic, IoT, and Wearable Electronic Gadgets!**

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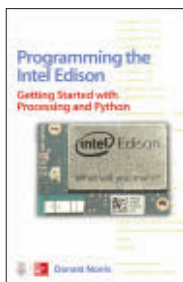
$20.00

Beginner's Guide to Reading Schematics, 3E
by Stan Gibilisco

Navigate the roadmaps of simple electronic circuits and complex systems with help from an experienced engineer. With all-new art and demo circuits you can build, this hands-on, illustrated guide explains how to understand and create high-precision electronics diagrams. Find out how to identify parts and connections, decipher element ratings, and apply diagram-based information in your own projects.
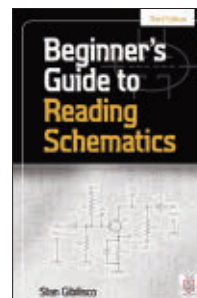
$25.00

### How to Diagnose and Fix Everything Electronic
by Michael Jay Geier

A Fully Revised Guide to Electronics
Repair all kinds of electrical products, from modern digital gadgets to analog antiques, with help from this updated book. The Second Edition offers expert insights, case studies, and step-by-step instruction from a lifelong electronics guru. Discover how to assemble your workbench, use the latest test equipment, zero in on and replace dead components, and handle reassembly. **$24.95**
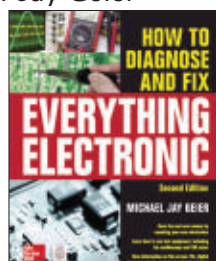
Programming PICs in Basic
by Chuck Hellebuyck

If you wanted to learn how to program microcontrollers, then you've found the right book! Microchip PIC microcontrollers are being designed into electronics throughout the world and none is more popular than the eight-pin version. Now the home hobbyist can create projects with these little microcontrollers using a low cost development tool called the CHIPAXE system and the Basic software language. Chuck Hellebuyck introduces how to use this development setup to build useful projects with an eight-pin PIC12F683 microcontroller. **$14.95**
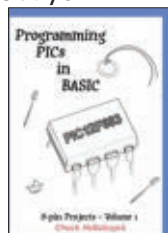
Programming Arduino Next Steps: Going Further with Sketches
by Simon Monk

In this practical guide, electronics guru Simon Monk takes you under the hood of Arduino and reveals professional programming secrets. Also shows you how to use interrupts, manage memory, program for the Internet, maximize serial communications, perform digital signal processing, and much more. All of the 75+ example sketches featured in the book are available for download. **$20.00**

■ BY FRED EADY

Getting Graphic(s) with the A40 Mesh Networking Alarm Controller Project

This edition of Design Cycle will wind up our A40 Mesh Networking Alarm Controller project. Even though we're focusing on the A40 design, this month's addition to that design can be used in any other project that requires an intelligent color touch display. Our backlit color touch display is a five inch beauty with a resolution of 800x480 pixels. All we need to communicate with the display is a serial port on our support hardware, which is driven by a PIC32MX575F512H. Graphic images for use with the display can be generated with just about any PC-based graphics application. If it sounds easy, it is. So, let's get started.

■ PHOTO 1. This unassuming shot is just the tip of the proverbial iceberg. The processing power of the display could have taken men to the moon and back graphically and in color.

■ FIGURE 1. The disk volume VP variables in this figure consist of just over 1 MB of volatile storage. TML files and Custom Memories are stored in the display unit's Flash.
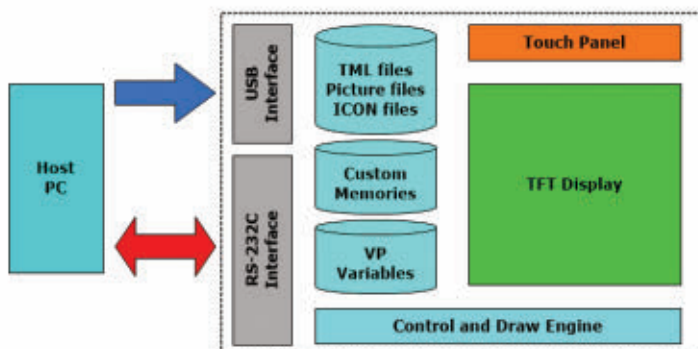
The Topway Display

The Topway touch panel we will be working with is actually a very powerful embedded computing platform. The display unit you see in **Photo 1** consists of a touch panel that overlays a five inch 800x480 pixel TFT display. The TFT display is supported by a display function controller, Flash memory, a ton of SRAM, an RS-232 interface, and power circuitry. We will interface our PIC32MX575F512H hardware to the display's RS-232 portal. A separate USB portal is provided by the display to accommodate loading the graphic application which we will generate with the Topway TML Graphics Editor. The touch panel's USB portal allows the display unit to appear as a USB drive to the host PC.

A block diagram of the display unit is drawn up in **Figure 1**. TML, picture files, and icon files are stored in the display unit's Flash memory area. The aforementioned Flash based files are preloaded via the display unit's USB interface. The files are moved from the host PC to the display unit Flash using a simple file copy. The TML files and associated pictures and icons form the basis for the touch display "application."

VP variables — which reside within the display unit's SRAM area — are accessible by the PC host via the RS-232 portal or internally to the display's TML application in real time. This means that the PC (or in our case, the PIC32MX575F512H) can move data to and from the display unit's SRAM. Using the services of the RS-232 portal, the display unit's VP variables can be stored and retrieved at will.

Data stored in Custom Memories can also be accessed via the RS-232 connection. The Control and Draw Engine is responsible for executing the

commands issued by the host, which is (in our case, once again) the PIC32MX575F512H support hardware. Real time touch key data is also generated and reported by way of the Control and Draw Engine using the services of the RS-232 portal.

The business end of the Topway display unit is smiling brightly in **Photo 2**. The 10-pin male header is exposing the display unit's RS-232 portal. Directly above the RS-232 portal is the USB interface which is used to preload the display unit. An onboard buzzer/beeper is mounted just under the flexible cable. To the immediate right of the buzzer/beeper is the battery that keeps the display unit's real time clock ticking. Power for the display unit — which happens to be 5.0 VDC — is taken from pins in the RS-232 interface connector.

The command sequences follow a communication packet structure format that consists of a packet header, command code, data/parameters, and a packet tail. The communication packet structure I just described is laid out in table form in **Figure 2**. Every command or data exchange begins with 0xAA and ends with the four-byte packet tail sequence. When things go as planned, the display unit returns a two-byte sequence of ":>" (0x3A, 0x3E).

The ":>" sequence signals that the last command was executed without error and the display unit's Control and Draw Engine is ready for the next command. The colon is replaced by an exclamation mark when a command or execution error occurs. Instead of returning ":>", the display unit will issue a "!>" sequence in the case of an error. If we happen to really throw the display unit a curve ball command, there is no response at all.

Command Sequence Visualization

The best way to understand how to write the PIC32MX575F512H communication sequence parser firmware is to issue commands via a terminal emulator and note the results. A good place to start is to issue a "hand shake" command. The hexadecimal command sequence for a hand shake is as follows:

```
0xAA 0x30 0xCC 0x33 0xC3 0x3C
```

The result of issuing the hand shake command can be
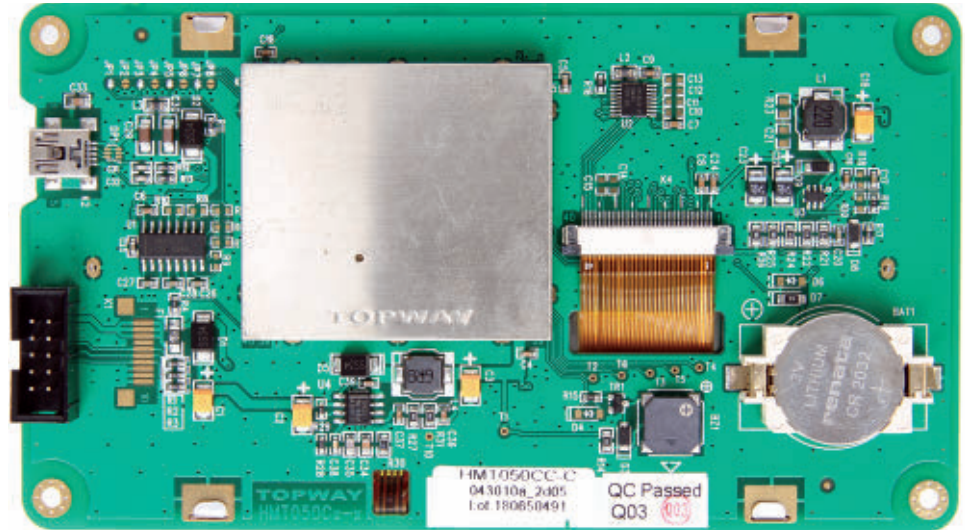
■ PHOTO 2. All of the magic is hidden under the shield. In addition to a powerhouse microcontroller, the Topway display unit sports a battery-backed real time clock and an onboard buzzer.


Seq	Code	Code Type	Description
1	0xAA	Packet Header	1 byte
2	Cmd Code	Command Code	1 byte
3	Parm or Data	Parameter or Data	Multiple Bytes
~	~	~	~
N-3th	0xCC	Packet Tail	4 bytes
N-2th	0x33		
N-1th	0xC3		
Nth	0x3C		

■ FIGURE 2. This communication packet structure is ideal for us as it is easy to verify and parse using some relatively simple C code and the PIC32MX575F512H.

seen in **Screenshot 1**. The first byte returned is the packet header (0xAA). The command issued is next followed by an ASCII text message from the display. The idea here is to ping the LCD and determine its status. In our case, the LCD responded and is ready for the next command.

Getting Touchy Feely

The Topway touch panel is attached via RS-232 to the CCS C Compiler's Serial Input/Output Monitor
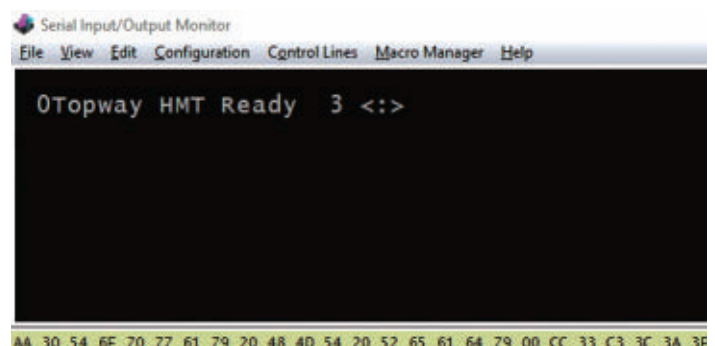
■ SCREENSHOT 1. The "hand shake" command (0x30) returns the command executed plus text signifying that the LCD is ready to rock.
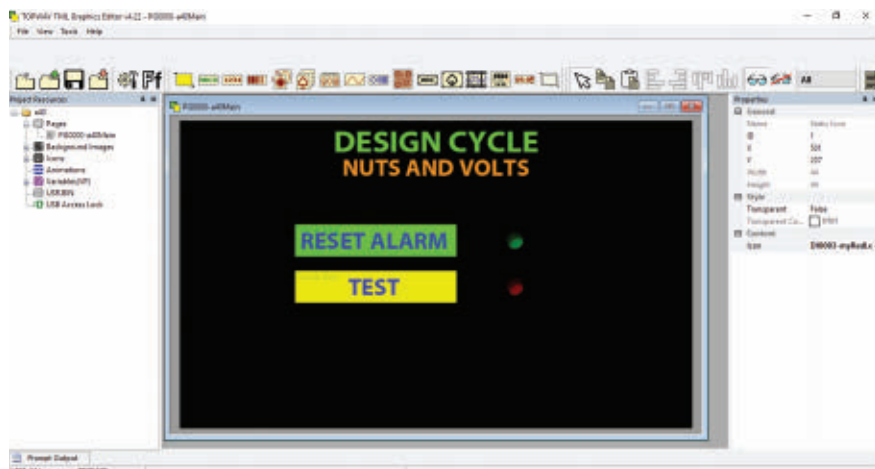
■ SCREENSHOT 2. This is a shot of the Topway TML Graphics Editor loaded with our touch application. Both the RESET ALARM and TEST buttons are configured as touch keys.

■ SCREENSHOT 3. As you can see, some of the characters returned by the Topway touch panel are not printable. That's okay as we're only interested in the hex representation anyway.

■ SCREENSHOT 4. The touch keys are identified by resident page and touch key ID. It's rather obvious that this capture is the code emitted following the fingering of the TEST key.

application, which comes as part of the CCS C Compiler package. I have loaded the Topway touch panel with the image you see in **Screenshot 2**. The RESET ALARM and TEST boxes are configured as touch keys. That means that when we touch either of those boxes, the Topway touch panel will emit a series of characters associated with each box or key. The idea is to be able to identify which box (key) was touched. Once we know which key was touched, we can act accordingly in our application.

Although each box (key) is positioned on the page at a unique XY coordinate, we won't identify the keys this way. Instead, each key will be identified by the page it resides on and an assigned touch key ID. The RESET ALARM key is configured as touch key 0, while the TEST touch key will report as touch key 1. With that, I've put a finger on the RESET ALARM key.

The Topway touch panel immediately responded with the string of hexadecimal characters you see in **Screenshot 3**. The first byte in the touch key response is

the standard Topway touch panel packet header byte (0xAA). The 0x78 in the return packet tells us that the response is a touch key ID response. The next pair of bytes (0x00 0x00) represents the page ID. If you look back at **Screenshot 2**, you will note that the page the touch keys reside on is identified as PG0000.

The next and final 0x00 byte is the touch key ID. In that this value is 0x00, that means I put my finger on the RESET ALARM box. The final four bytes (0xCC 0x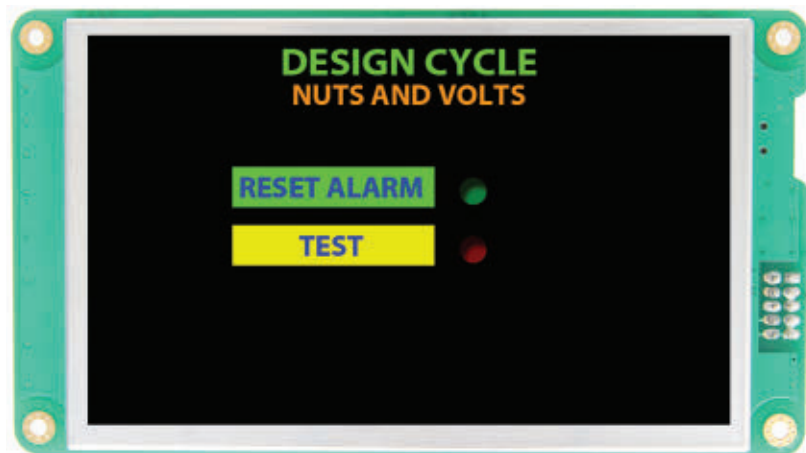33 0xC3 0x3C) are the communication packet tail characters which are common to every packet emitted by the Topway touch panel. Just for grins, I've touched the TEST key in **Screenshot 4**. You can easily see that the touch key ID field has changed from 0x00 to 0x01.

Object Manipulation

We have complete control over what is presented on the Topway touch panel display. We have the ability to place icons, text, keyboards, and other visual objects at will. **Photo 3** depicts our current application display of two touch keys and a pair of red and green LEDs. The virtual LEDs are shown in their "off" states in **Photo 3**.
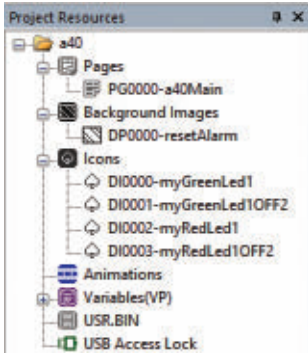
We want the virtual LEDs to toggle between

■ PHOTO 3. This is our application "look." Ultimately, we want to be able to toggle the virtual LEDs and process the touch key responses within our application.

■ PHOTO 4. The virtual green LED is "on" and I didn't have to switch a transistor or microcontroller I/O port to make it shine.

■ PHOTO 5. If we wish to illuminate both virtual LEDs, it is easily done. Here is the result of executing the display icon command with the red virtual LED XY coordinates.
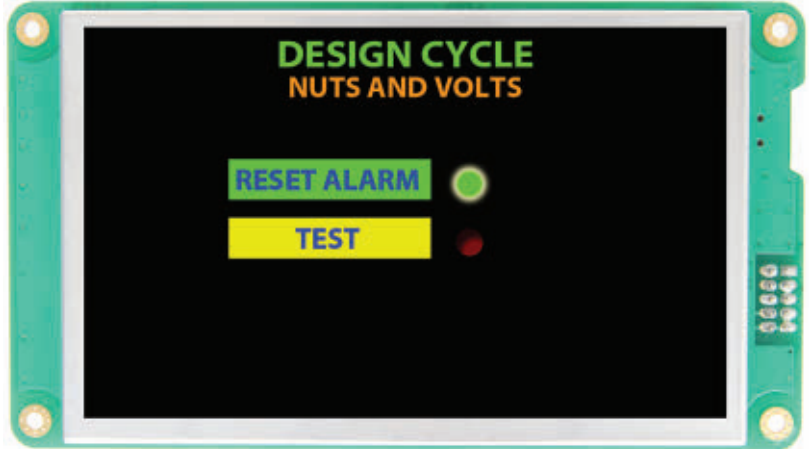
"on" and "off" or illuminated and not illuminated. Naturally, our virtual LEDs have no electrical connections. So, we'll have to simulate real LEDs with visual trickery. We perform this visual magic by placing on and off LED icons on the display.

The green virtual LED is located at X = 501 and Y = 165 on the face of the Topway touch panel display. Currently, the off icon is in this position. **Screenshot 5** exposes all of the visual resources we have at our disposal. There, visual objects are either imported into our project or created within our project. For instance, we create pages and fill them with imported background images. Our pair of red and green virtual LEDs are represented as four individual icons. To turn our green virtual LED on, we simply place the *myGreenLed1* icon at coordinates X=501 and Y = 165. To turn the green virtual LED off, we call upon the *myGreenLed1OFF2* icon to replace the *myGreenLed1* icon at the same position.

Let's turn the green virtual LED on. We'll use the Topway touch panel's display icon command and the XY coordinates of the virtual green LED to make it happen. Here's the layout of the command sequence:

```
0xAA   Communication Packet Header
0x9E   Display Icon Command
0x00   Green Icon ID High Byte
0x00   Green Icon ID Low Byte
0x01   X Coordinate High Byte
0xF5   X Coordinate Low Byte
0x00   Y Coordinate High Byte
0xA5   Y Coordinate Low Byte
0xCC   Communication Packet Tail
0x33
0xC3
0x3C
```

The green LED on icon is identified as DI0000 in our Topway touch panel visual object manifest. All we need to do is translate the XY coordinates of the green virtual LED to hexadecimal and insert them into the packet. **Photo 4** is the result we obtained after the display icon command packet was received by the Topway touch panel.
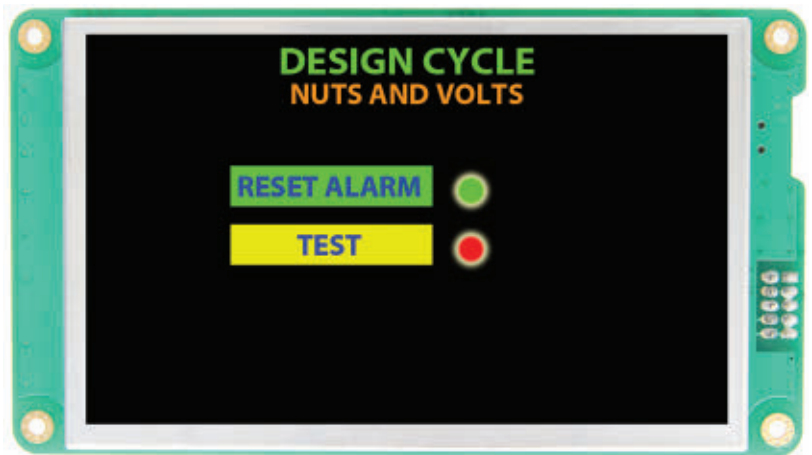
Here's how we illuminate the red virtual LED:

```
0xAA   Communication Packet Header
0x9E   Display Icon Command
0x00   Red Icon ID High Byte
0x02   Red Icon ID Low Byte
0x01   X Coordinate High Byte
0xF5   X Coordinate Low Byte
0x00   Y Coordinate High Byte
0xED   Y Coordinate Low Byte
0xCC   Communication Packet Tail
0x33
0xC3
0x3C
```

The red virtual LED is on the same X axis as the green virtual LED but with a differing Y coordinate of 237. Both virtual LEDs are now illuminated in **Photo 5**.

Touch Key Coding

Now that we know what to expect when a touch key is engaged, let's think about how to gather the incoming

information. We'll need to allocate some specific buffer spaces to hold the incoming information. Let's start by defining a structure to contain the touch key ID information:

```
typedef struct{
    BYTE cmd;
    BYTE pageIDh;
    BYTE pageIDl;
    BYTE keyID;
}TOUCHRESPONSE;
TOUCHRESPONSE resp;
```

Doing this will allow us to easily store and access the incoming touch key ID information. For instance, we want to get the value of the command byte:

```
BYTE commandByteVal;
commandByteVal = resp.cmd;
```

Our application may want to use the incoming *pageID* information in a 16-bit form. We have it in the form of *resp.pageIDh* and *resp.pageIDl*, but that's in eight-bit form. So, let's write a macro that will combine two eight-bit values into a single 16-bit value:

```
#definemake16(varhigh,varlow)
(((unsigned short)varhigh & 0xFF)* 0x100) +
((unsigned int)varlow & 0x00FF)
```

The definition of the *make16* macro allows us to do this:

```
WORD pageIDval;
pageIDval = make16(resp.pageIDh,resp.pageIDl);
```

Let's do our original code one better. We'll add the 16-bit *pageID* value to our *resp* structure so we can access it as *resp.pageID*:

```
typedef struct{
    BYTE cmd;
    BYTE pageIDh;
    BYTE pageIDl;
    WORD pageID;
    BYTE keyID;
}TOUCHRESPONSE;
TOUCHRESPONSE resp;
```

Now that we have allocated some space for our touch key ID information, let's go about gathering it via the PIC32MX575F512H's RS-232 interface. The PIC's RS-232 interface is interrupt driven. So, our *CharInQueue4* function checks for a received character that has been stuffed into the receive circular buffer, and the *recvchar4* function removes the received character from the circular receive character buffer.

We know that a valid communication packet from the Topway touch panel begins with the hexadecimal value of 0xAA. So, that's our first target:

```
BYTE getLCDpacket(void)
{
    BYTE lcdPktHdr;
```

```
BYTE rxBufLCD[16];
    if(CharInQueue4())
    {
        //look for 0xAA
        lcdPktHdr = recvchar4();
```

Once we've assured ourselves that a valid packet is being transmitted, the next step is to pick up the command/response byte and place it into *resp.cmd*:

```
        if(lcdPktHdr == 0xAA)
        {
            tdelayms(1);
            if(CharInQueue4())
            {
                //get command code
                resp.cmd = recvchar4();
            }
            else
            {
                //no good.. get out
                return(1);
            }
```

If the command code/response byte is sour, we throw the whole thing away and wait for the next incoming data stream. Otherwise, we continue the reception of the incoming data stream and make an attempt at recovering the actual key touch ID data:

```
        switch(resp.cmd)
        {
            case 0x78:
                //get key ID data
                resp.pageIDh = recvchar4();
                resp.pageIDl = recvchar4();
                resp.pageID = make16(resp.
                   pageIDh,resp.pageIDl);
                resp.keyID = recvchar4();
```

At this point, things look okay. However, there's still the communication packet tail to take aboard and analyze:

```
                //get comm tail
                rxBufLCD[0] = recvchar4();

                rxBufLCD[1] = recvchar4();

                rxBufLCD[2] = recvchar4();

                rxBufLCD[3] = recvchar4();
                //verify comm tail
                if(rxBufLCD[0] == 0xCC && \
                   rxBufLCD[1] == 0x33 && \
                   rxBufLCD[2] == 0xC3 && \
                   rxBufLCD[3] == 0x3C)
                {
                    //do what is necessary
                    //here
```

Once the entire touch key ID packet is received and parsed, we are okay to go ahead and continue with the application flow.

Visual Trickery

We can receive the touch key ID information. Let's put ourselves in the position to manipulate the virtual LEDs as we wish. To do that, we must code a simple but

powerful function called *showIcon*. The name of our function says it all. We'll use the *showIcon* function to swap in and out the virtual LED on and off images. The whole thing is based on a core function that sends a single byte via the PIC32MX575F512H's UART4:

```
void sendBiteUart4(BYTE c)
{
        U4TXREG = c;
        while(U4STAbits.TRMT == 0);
}
```

From what we know at this point about the Topway touch panel's communication packet structure, the following code should be familiar:

```
#define make8dw(var,offset) ((unsigned long)var
>> (offset * 8)) & 0x000000FF

BYTE showIcon(WORD iconID,DWORD xyCoord)
{
        WORD timeoutms;
        BYTE indx;
        BYTE rc;

        rc = 0;

        sendBiteUart4(0xAA);
        sendBiteUart4(0x9E);
        sendBiteUart4(make8(iconID,1));
        sendBiteUart4(make8(iconID,0));
        sendBiteUart4 (make8dw(xyCoord,3));
        sendBiteUart4 (make8dw(xyCoord,2));
        sendBiteUart4 (make8dw(xyCoord,1));
        sendBiteUart4 (make8dw(xyCoord,0));
        sendBiteUart4(0xCC);
        sendBiteUart4(0x33);
        sendBiteUart4(0xC3);
        sendBiteUart4(0x3C);
```

Our *showIcon* function follows the convention of sending a packet header byte (0xAA) followed by the command byte (0x9E). If you recall, the command byte we are transmitting is the display icon command byte. Following the display icon packet format, after the header and command are sent, we send the icon ID and the XY coordinates where the icon should be placed. To make it all legal to the Topway touch panel, we finish off the packet with the quartet of tail bytes.

Hold it. The play is not over yet. Although we sent the "right stuff," that doesn't mean it got there okay. We'll need some proof of receipt. Here's how we verify that our request was honored:

```
    memset(okBuf,0x00,sizeof(okBuf));
    indx = 0;
    timeoutms = 5000;
    do{
        if(CharInQueue4())
        {
            do{
            okBuf[indx++] = recvchar4();
            }while(CharInQueue4());
        }
            tdelayms(1);
    }while(—timeoutms && strcmp(lcdOK,okBuf)
```

```
!=0);

    if(timeoutms)
    {
        rc = 1;
    }
    return rc;
}
```

We will give the Topway touch panel five seconds to respond good or bad. We are looking for the Topway touch panel OK response:

```
    const BYTE lcdOK[] = ":>";
```

Once we receive the ":>" sequence, we can rest assured that our display icon command was executed according to our parameters.

A40 On Station

You now have everything you need to put together an A40 Mesh Networking Alarm Controller solution. You're also checked out on the Topway touch panel. Now, smile and stuff this A40 and Topway touch knowledge into your Design Cycle tricks bag. **NV**

Virtual Instruments Improve Electronic Experimentation

A bench full of test equipment for only a few hundred dollars.

As electronic experimenters, we all build a variety of circuits and gadgets. That means we usually have to test and troubleshoot these projects. The main instrument we use for this is the digital multimeter (DMM). It can measure voltage, current, and resistance. Some DMMs even measure capacitance and transistor gain. Yet this capability is often not enough. What we really need is an oscilloscope so we can see the signals in our circuits. A scope is particularly helpful when we are using high frequency digital logic, microcontrollers, and RF ICs.

But that's not all. Some projects require a signal generator. Wouldn't it be great to have a logic analyzer? How about a spectrum analyzer? Dream on. If you are a serious enough experimenter, you may already have a scope and some other test gear. Many of you are serious experimenters but don't have a big enough budget for a scope, much less project parts or other test gear. There is a solution for this that you may not have thought of: virtual instruments (VIs). For just a few hundred dollars, you can have a whole bench full of high quality test instruments of the VI type.

What is a Virtual Instrument?

A VI is a software-based instrument that uses a PC desktop or laptop for its processor and screen. The VI hardware for a scope is a small box with a fast analog-to-digital converter (ADC) that is used to digitize the signal to be observed. The ADC samples the input signal and stores the digital samples in memory. Special software then uses these samples to reconstruct the signal for display on the video monitor or LCD screen. The software also formats the screen to look like a typical scope display with its measurement graticule, and implements controls to vary horizontal sweep timing, triggering, and amplitude adjustment. It is also possible to implement dual or four channels of input for concurrent display.

To implement a signal or function generator, the software stores digital samples of desired output waveforms like sine, square, or triangle waves. These samples are fed to a digital-to-analog converter (DAC) that generates the analog output signal. The software also provides a screen showing the output as well as the controls for output frequency and amplitude. Some VIs incorporate an arbitrary waveform generator (AWG) that lets you create special output waveforms that you may need for testing.

Other VIs are also possible. A popular one is a spectrum analyzer that shows signal power plotted over frequency. Commercial spectrum analyzers cost thousands of dollars. A VI spectrum analyzer takes the input signal digital samples and uses a mathematical algorithm called the fast Fourier transform (FFT) to generate the displayed signal in the frequency domain. The PC does all of the heavy computing required by the FFT software.

The VI idea was pioneered by National Instruments (NI) who created the well-know VI software called LabVIEW. It was used on the early Apple Macintosh computers to work with NI's data acquisition products. Today, most modern test instruments are essentially software based with built-in displays. However, you can also buy a cheap VI in a small box to use with

Post comments on this article and find any associated files and/or downloads at
www.nutsvolts.com/magazine/article/august2016-Open-Communication-virtual-instruments.
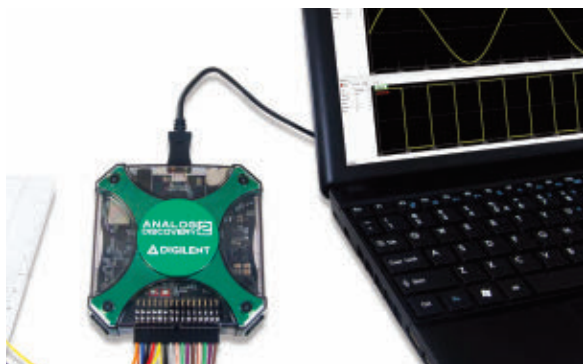
your PC to produce several very useful test instruments. The rest of this story gives some examples.

The Analog Discovery 2

The Analog Discovery 2 is a full blown VI in a small box as shown in **Figure 1**. It is made by Digilent, Inc., which is a company that is owned by National Instruments. All of the ADCs, DACs, and other circuits are in the small enclosure. The whole thing is powered by the +5 volts from the USB connection to the laptop. The VI software that creates all the instruments is called Waveforms and is installed on the laptop. The software runs under Windows, Apple Mac OS, or Linux. The colored wires are all of the inputs and outputs (I/O) that connect to external circuitry. This photo shows the outputs from two function generators displayed on the dual trace oscilloscope. Special pins are used with the I/O leads to connect to the circuits on the breadboarding socket.

The amazing thing is what the Discovery 2 implements. Take a look at what's inside the box:

- Two-channel USB digital oscilloscope (1MΩ, ±25V, differential, 14-bit, 100 Msample/sec, 30 MHz+ bandwidth — with the Analog Discovery BNC Adapter Board)
- Two-channel arbitrary function generator (±5V, 14-bit, 100 Msample/sec, 20 MHz+ bandwidth — with the Analog Discovery BNC Adapter Board)
- Stereo audio amplifier to drive external headphones or speakers with replicated AWG signals
- 16-channel digital logic analyzer (3.3V CMOS, 100 Msample/sec)
- 16-channel pattern generator (3.3V CMOS, 100 Msample/sec)
- 16-channel virtual digital I/O including buttons, switches, and LEDs — perfect for logic training applications
- Two input/output digital trigger signals for linking multiple instruments (3.3V CMOS)
- Single-channel voltmeter (AC, DC, ±25V)

- Network analyzer — Bode, Nyquist, Nichols transfer diagrams of a circuit. Range: 1 Hz to 10 MHz
- Spectrum Analyzer — power spectrum and spectral measurements (noise floor, SFDR, SNR, THD, etc.)
- Digital bus analyzers (SPI, I²C, UART, Parallel)
- Two programmable power supplies (0 to 5V, 0 to -5V). The maximum available output current and power depend on the Analog Discovery 2 powering choice:
  · 250 mW max for each supply or 500 mW total when powered through USB
  · 700 mA max or 2.1W max for each supply when using an external wall power supply

It literally is a whole test bench of instruments that you usually need when experimenting, designing, troubleshooting, or otherwise playing around with circuits or equipment. All this costs is $279. Individual test instruments with these specs would cost you thousands of dollars. Save up. It is worth it.

A lower cost version called the Analog Discovery is also available for $249. The scope and AWG bandwidths are only 5 MHz, and the power supply current capability is more limited to 50 mA. This will restrict your range of applications. Go for the $30 extra and get the Discovery 2. I also recommend their BNC connector adapter board that lets you use standard scope probes that will give you the full 30 MHz bandwidth. They also have a wall wart transformer power supply if your power supply needs exceed the capability of the USB port.

Another Option

There are other similar products on the market. A couple of years ago NI introduced their myDAQ product (see **Figure 2**). This device uses a reduced version of

FIGURE 1. Digilent's Analog Discovery 2 virtual instrument package. Connect it to a laptop via a USB cable and you have a full work bench of test equipment.

FIGURE 2. National Instruments' myDAQ virtual instrument and educational trainer. It is widely used in colleges and universities giving students a portable lab.

LabVIEW software to implement the instruments. NI myDAQ includes two analog inputs and two analog outputs at 200 kS/s and 16 bits, allowing for applications such as sampling an audio signal. It also has eight digital inputs and output lines; +5, +15, and -15 volt power supplies; and a 60V DMM to measure voltage, current, and resistance. The myDAQ connects to the PC via a USB cable. Connections to the circuits under test are by way of screw terminals. The primary limitation of the myDAQ is its limited scope and generator bandwidths making it suitable only for audio frequency range signals or just above.

The myDAQ is widely used by students in colleges and universities who can run their lab experiments and exercises in their dorm room or at home instead of the college lab. A considerable amount of lab manuals and other courseware has been developed around the myDAQ. The cost is typically $400 but special student and educational discounts are available.

FIGURE 3. The Velleman PCSU1000 is a two-channel virtual oscilloscope with a 60 MHz bandwidth. It includes a spectrum analyzer function.

Just the Oscilloscope

There are also products that just implement the scope rather than the full instrument package. A good example is Velleman's PCSU1000 two-channel USB oscilloscope; refer to **Figure 3**. The sampling rate is 1 Gb/s and the bandwidth for each channel is 60 MHz. The PCSU1000 also includes a spectrum analyzer function. **Figure 4** shows a screenshot of the scope doing an FFT that produces the spectrum display. It can handle input signals in the 1.2 kHz to 25 MHz range. The price is $249.

Velleman also makes the lower priced PCSU200: a dual channel scope with a function generator. It has scope input bandwidths of 12 MHz. A spectrum analyzer function good to 12 MHz is also included. The function generator produces sine and square waves from 0.5 Hz to 500 kHz (or 1 MHz for the sine). Price is $179.85.

Another scope supplier is PicoTech. Their PicoScope product line is extensive. They offer dozens of models that range in price from a few hundred dollars to thousands of dollars. Bandwidths vary from 10 MHz to 20 GHz. Most models have a built-in AWG.

Next time you are ready to spend on your experimentation, consider one of these items that will greatly expand your scope and capabilities. **NV**
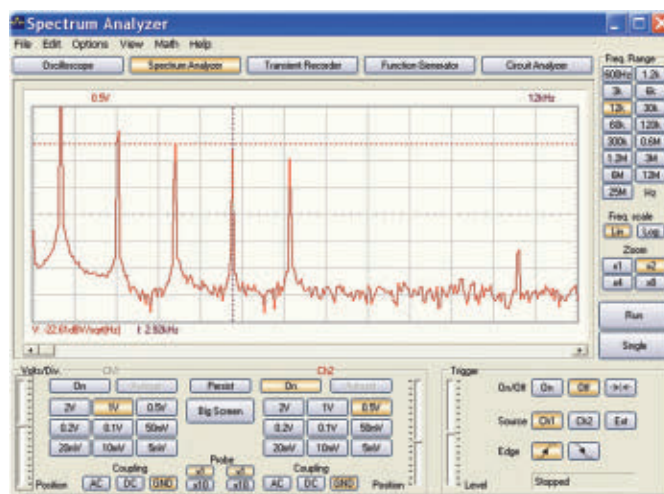
FIGURE 4. Screenshot of the spectrum analyzer feature on the Velleman PCSU1000 scope.

fingertip where it touched the screwdriver; just a small circle on the outer skin like when you scratch it. I never lost any feeling, and 40 years later I am fine. I believe strongly in the one hand rule around HV. Had my other hand touched the transmitter, I wouldn't be writing this.

David S. Powell
Lexington, KY

Thanks for sharing, David. Luckily, I've never had your experiences. Perhaps some of our readers will have had similar encounters. Glad you didn't have any lingering effects.
Bryan Bergeron

What's Important to You is Important

Regarding the Developing Perspectives in the July 2016 *Nuts & Volts* ... In my mind, you have really unleashed a hornet's nest.

I grew up with R-390s, UA741, TTL logic, and have played with Fortran4/77, BASIC Stamps, Perl, TNCs, and many other aspects of being a professional technician and ham radio operator. I maybe, kinda, might understand your framing of "fiscal irresponsibility" but ...

My frame is that you have to do "what is important to you." A couple of caveats are that I have a decade or so on you for age and some pressing medical issues, but enough whining.

I have forced myself to refocus on "what is important to me." I would love to continue exploring everything that I have experienced over 74 years, but the day just ain't long enough. I struggle every day with the "what is important today" and I manage to have fun doing it, mostly.

On one hand, my enjoyment in repairing that old Heathkit SB-301 is certainly fun (important to me), but regular reading of electronics magazines (the few that are still here) prompts me to be involved in writing code for the homebrew projects that I work on, or tweaking the newest router for the network or learning all

about FPGAs (other importants to me/other unclimbed moutains).

I haven't managed to pry my hands off the SB-301 yet, but it will probably happen due to the focus issue (what is important to you or is it "Damn, everything just keeps on a changin").

Ron KE7RT

I appreciate the feedback, Ron. I agree with you that you've got to do what's important to you, regardless of what anyone else thinks (well, you might want to take your significant other's perspective into consideration).

Using 3D printers for practical projects on your workbench.

Soldering Wires with a 3D Print

For years, I've used a third hand (also called a helping hand or extra hand) for holding circuit boards and soldering wires. The adjustments on the third hand make it difficult to get wires to line up just right. The wires sag or bend away from where you want them to be. The alligator clips on the wires can also cause damage to the insulation.

3D Design

I've shown in previous articles that 3D printed circuit board holders can be designed and printed or downloaded from **Thingiverse.com**. So, I decided to look for any options to hold wires in place. I found a design from Thingiverse user, Landin81. He calls it the Solder Cableholder. The design is rather simple but very useable. He designed it with three separate sized angled slots. This allows it to automatically fit and hold wires of various sizes. A little bending and the ends of the wires are touching and ready for solder.

The design is small enough to print on just about any 3D printer. I printed one on my small Fabrikator Mini that I've shown in previous articles. I printed it in green PLA plastic which is actually a low melting point plastic, but certainly well equipped for this design. The wires shouldn't get hot enough to melt the plastic.

Fabrikator Mini

I've printed ABS plastic on my Fabrikator Mini, which is the same plastic used in LEGO Blocks. It has a higher melting point than PLA, so that is also an option if you are worried about temperature. So far, however, PLA has

■ FIGURE 1. Third hand.

worked fine for me. I find so many small useful designs like this that I can print on this little desktop printer. My only complaint about the Mini is they sell out fast at **Hobbyking.com** and they take forever to get more in stock. I added an LCD and SD card module to mine so I can print disconnected from the computer.

Post comments on this article and find any associated files and/or downloads at
www.nutsvolts.com/magazine/article/august2016-Practical3DPrinting.
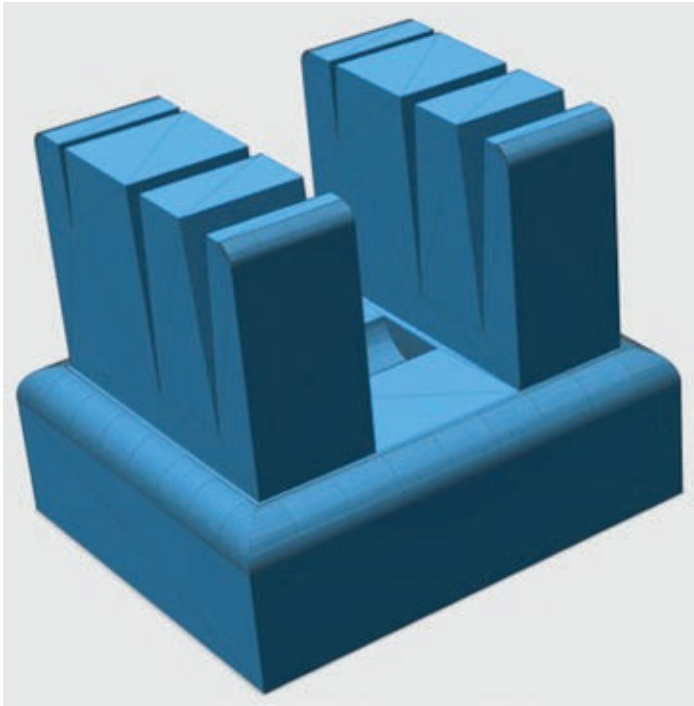
■ **FIGURE 2. Solder Cableholder.**

The design can also be enlarged to hold large wires, but most of the wiring I use in my electronics workshop fit fine in this design. Plus, since it's a 3D print, making a new one if something melts is easy to do.
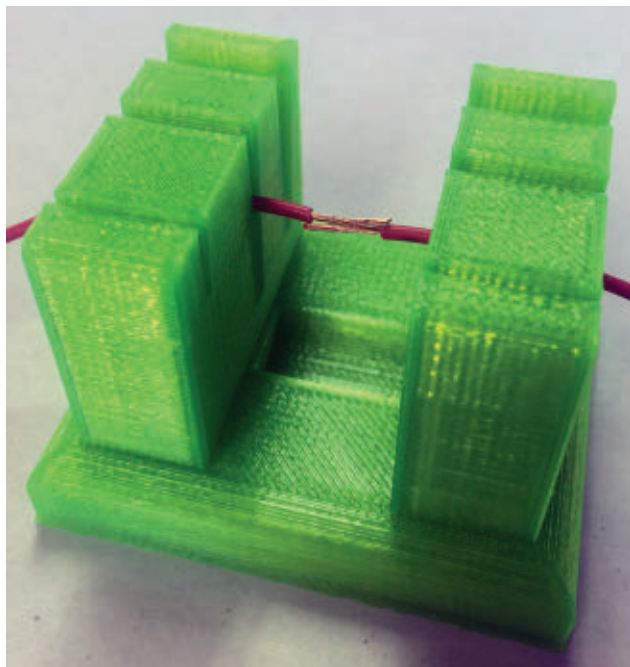
■ **FIGURE 4. My solder holder.**
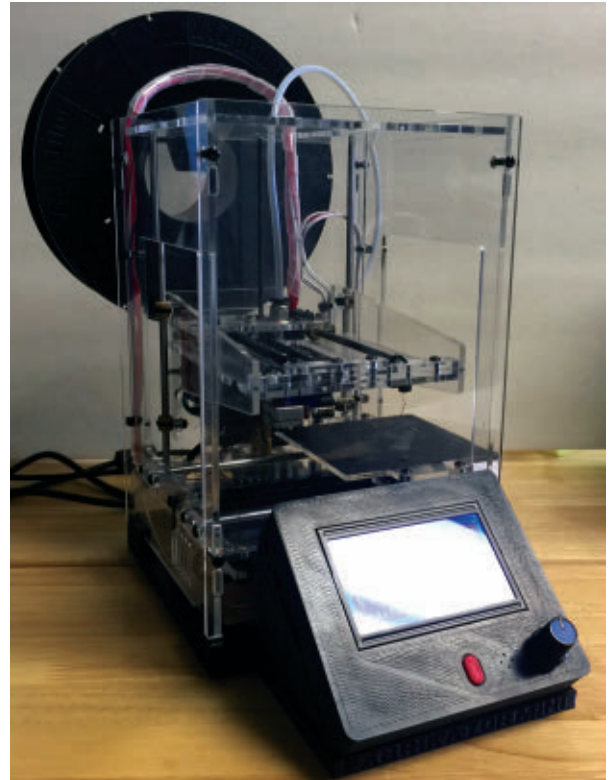
■ **FIGURE 3. My Fabrikator Mini 3D printer.**

My 3D Print

I printed mine at a 0.2 layer height and 50% fill because I wanted it solid. I use Simplify3D software to slice my prints. A slicer takes the .stl file and turns it into G-Code that the printer understands. It's like an assembler for a microcontroller.

I used a green PLA but any color would work. The 50% fill makes it a little heavier as well, but after I printed it I thought I could have edited the .stl file to have space in the base for metal washers to give it more weight. This is easy to do as you just pause the print while it's printing the base, put the metal washers inside, then un-pause it and let the print finish, locking the heavy washers inside.

My printed version is shown in **Figure 4**. It shows wires in place ready to solder. One flaw, though, was heat shrink tubing. On the third hand, I could install heat shrink tubing on the wire and then use a heat gun to shrink it around the solder joint. The plastic version didn't like that much as the plastic quickly gets soft with a heat gun blowing on it. So, it's not a perfect solution but it does have advantages over the third hand. What I ended up doing was sliding the wire farther out to the side of the mount so the heat shrink was away from the plastic holder. Then, I could shoot it with heat.

Solderless 3D Printing

Another option for 3D printing is when you want to make a connection without wire, one of those conductive inks or glues make a great option; you just need a way to guide the ink. In a previous Filament Friday video on my YouTube channel, I made a miniature traffic light. I designed it in Tinkercad and made grooves for conductive glue (that I found at RadioShack) to lie into. I applied the conductive glue to the grooves or channels, and then I added a couple LEDs and a few connection wires at the bottom. I let the glue dry and I had my circuit.

From there, I could control it from an Arduino on a breadboard. This was a fun project using 3D printing to essentially make a custom circuit board. Instead of removing copper by etching, I just designed the traces as channels and then added the conductive material.

Summary

3D printing can be used to make many different useful tools. I show a lot of my creations on my YouTube channel (**FilamentFriday.com**) that I create in Tinkercad.

Sometimes its nice to find something I can just print and use. **Thingiverse.com**, **myminifactory.com**, and **pinshape.com** are just a few of the sites I like to search for designs. There is no end to what you can find to print on your 3D printer.

Once you have one, you'll wonder how you got away with not having one for so long. **NV**
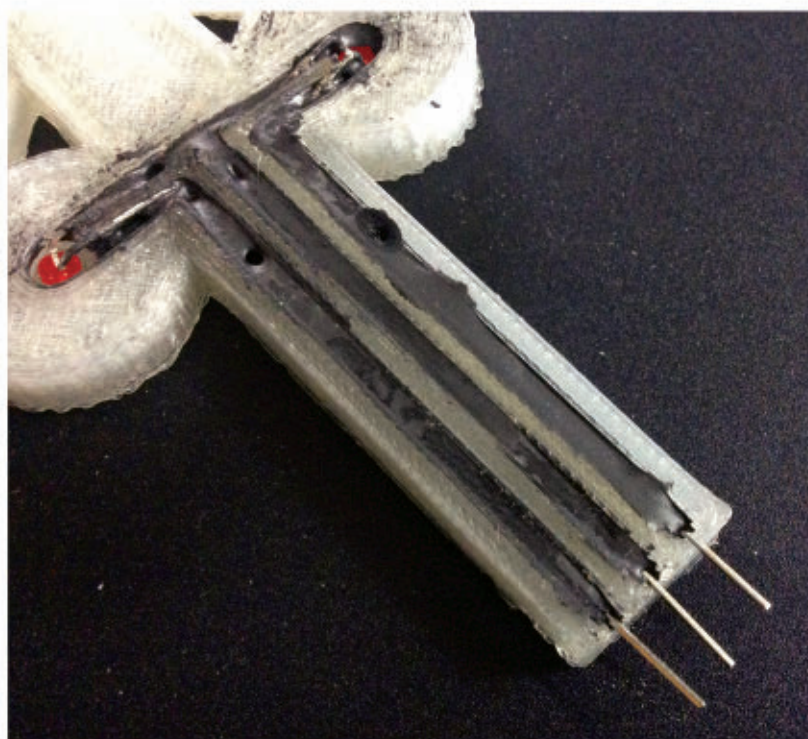
■ **FIGURE 5. Conductive glue 3D printed traffic light.**
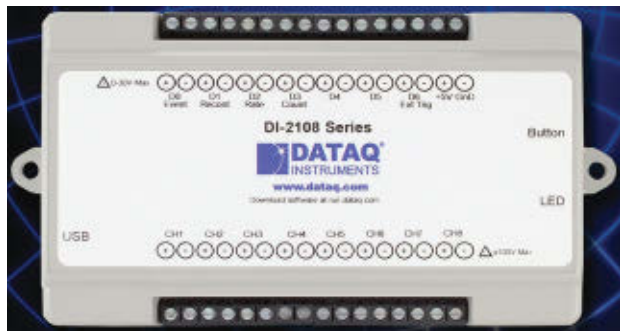
±10V measurement span, 16-bit resolution, and anti-alias filters that automatically adjust with sample rate. The DI-2108 also provides seven digital ports — each configurable as an input or a switch. Two ports can be programmed as counter and frequency measurement inputs. The instrument's maximum sampling throughput rate is 220 kHz.

The DI-2108 employs a 120 MIPS processor that performs a continuous 512-sample CIC filter calculation per enabled channel; this is the same technology that is vital to high volume wireless communication networks.

Overvoltage protection up to ±100V DC or peak AC protects the instrument from measurement mishaps. Software support includes ready-to-run WinDaq data acquisition software, ActiveX controls, and a fully documented communication protocol to deploy the instrument on any platform. The DI-2108 includes a USB cable, connection terminal screwdriver, WinDaq software, and all programming tools.

For more information, contact:
DATAQ Instruments
www.dataq.com

1 kHz HANDHELD
LCR METER

B&K Precision has announced the expansion of its current 878B and 879B 40,000-count handheld LCR meters with the addition of a new 100 kHz model: the 880. This new portable LCR meter can measure inductance, capacitance, and resistance with 0.1% basic impedance accuracy. Offering many features typically found only in bench LCR meters, the 880 provides test frequencies up to 100 kHz, selectable test signal levels, and four-terminal measurement capabilities. With a fast auto-ranging function, convenient single-push auto-detect mode, and versatile functions such as data recording, tolerance sorting, and relative mode, the 880 is suitable for characterizing components in the field or laboratory environments.

Four-terminal shielded configurations can help minimize measurement errors and improve measurement accuracy. Using four-terminal Kelvin test leads can help mitigate the effect of lead impedances and contact resistances. The 880 offers a four-terminal socket with separate sensing and current leads, plus a guard terminal.

The 880 features a dual display with 40,000-count and 10,000-count resolution for primary and secondary measurements, respectively. Selectable test frequencies include 100 Hz, 120 Hz, 1 kHz, 10 kHz, and 100 kHz, along with selectable test levels of 0.3 Vrms, 0.6 Vrms, and 1 Vrms. In addition, the LCR meter provides DC resistance measurement capability. Standard accessories include an AC adapter with rechargeable 9V battery, mini USB cable, shorting plate, banana to alligator test leads, Kelvin clip test leads, and additional tweezer accessory for convenient measurement of SMD components.

The handheld LCR meter comes with a three year warranty and is listed at a price of $399.

For more information, contact:
B&K Precision
www.bkprecision.com

CLASSIFIEDS

>>> QUESTIONS

Smart Wallet?

My old billfold was worn out over the years. I planned to retire it when I noticed in back was a coil of 10 revolutions (6 cm x 4.8 cm) with a capacitor marked 47 soldered to the ends, welded in plastic, the size of a credit card. I had never noticed this. Could it be a security feature to prevent devices from getting to my credit card? How would it function? Just curious. A picture of it is shown above.

#8161 **Christian Bock**
via email

Temperamental Trailer

The lights on my boat trailer work erratically. Sometimes they work fine (turn signals, brakes, and running lights); other times, when I press the brake pedal, only the right turn light comes on and all the running lights go out! Short of tearing it all out and re-wiring from scratch, any tips on how to locate the fault and fix it?

#8162 **Craig Priolo**
Saint Louis, MO

Is It Dumb To Have A Smart TV?

Is it possible (or even necessary) to try to protect my "Smart" TV from hackers? If so, what are the issues and where is the best place to start?

#8163 **Maurice Scalf**
Brea, CA

How Long Is 9 Volts?

Is there a simple way to determine how long a given circuit will run on a standard 9V battery?

#8164 **Janet Patel**
Amarillo, TX

Unwired

I want to extend my home alarm system to my garden shed. The shed has power but no simple way to get wire to it from the house. Is there a DIY wireless method to try?

#8165 **Woodrow Young**
Lima, OH

Water Wise

I would like to add a "rain detector" to my sprinkler system that would automatically disable the sprinklers. The system uses an old-style mechanical "dumb" timer. How about a simple circuit to do the job?

#8166 **Gary Hunt**
Southfield, MI

Camptronics

It has fallen to me to teach a short course on electronics for a summer camp program near our home. I would welcome suggestions for curriculum! The kids are ages 8-12.

#8167 **Levi Coughlin**
Dunmor, KY

>>> ANSWERS

[#5162 - May 2016]
Data Transfer Dilemma

I am a mechanical engineering consultant by profession. I design the mechanical and hardware/software for my client's ideas and projects. I then 3D print the mechanical components, fabricate the PCBs, put everything together, and provide my clients with working production-intent prototypes.

One of my elderly friends came to me with an antiquated product called "The Electronic Rolodex 128k." He asked me how he could get the data onto his computer because the LCD on this device is starting to fail and he is no longer able to read the names and phone numbers. I dabble enough in this area where I said that I am very capable of figuring this out. So, I took on the challenge.

The only data I/O on the device is an IR transmitter on the left side and an IR receiver on the right. There are NO serial ports or any other connectors that would enable me to connect to a computer. The purpose of the left and right transmitter and receiver is so that if you have two identical devices, you can transmit the data from one device (on the right) to the other device (on the left).

I borrowed an IR to USB adapter from a friend and opened up a Tera Term window. I also used my signal analyzer to determine the appropriate baud rate (4800). I can see the data reception and it seems that I am receiving complete garbage characters. I have played with my signal analyzer and have inverted the

Send all questions and answers by email to **forum@nutsvolts.com**
or via the online form at **www.nutsvolts.com/tech-forum**

signal, swapped LSB and MSB, and many other tweaks.

When that didn't work, I opened up the device and soldered leads directly to the TX and GND pins at the IR transmitter. I then connected the leads to my signal analyzer and also my oscilloscope. I verified the baud rate and also noticed that the voltage levels were TTL, not RS-232. I borrowed a TTL to USB adapter, but this did not work either.

I came to terms with the fact that the data is compressed and/ or encrypted. So, I searched far and wide for some software for this device and I found it ... well at least a similar device. I installed and ran it in a variety of configurations and still cannot get receive data that makes any sense. I have done enough testing and playing around with this product where I can almost write a book, but I still have no success in transferring the data to another similar device or to a computer. I have searched for this device on Google, eBay, Amazon, etc., and they are extinct. I've purchased a slightly newer generation of this product, but I do not believe that they are compatible. I have called the manufacturer, but they no longer support the device. So, I am at a total dead end. I have read your magazine for many years and thought that this would be the perfect venue for a Nuts & Volts case study/project for DIYers and the like. I would greatly appreciate any advice that you might have in doing what I originally expected to be a relatively simple problem to solve.

#1 Have you opened the device and identified its processor? The data through the IR ports may be compressed, but the data sent to the display isn't compressed, and maybe easier to capture as LCD digits and segments. Then, you can convert that back to ASCII and send it to a new computer.

The next problem is how to attach to the LCD digit and segment signals without doing any damage to the original device. The scan frequency is necessary to sync the signals at the right moment when being read. The processor ID will give you the correct signal pins and help reading through a second device.

The last solution is to read the data on the LCD one-by-one and type the information manually to the newer computer. It may be the only non-invasive solution.

Raymond J Ramirez
Bayamon, PR

#2 Wow, lots of work so far! Could you stick a chip clip on the memory chip and monitor it while trying a transfer (to force it to dump the DB)? Maybe it isn't encrypted until the IR transfer; that is, unencrypted coming out of the memory chip ... obviously, assuming there is one.

Pete Lunt
Cary, NC

#3 "Google is your friend," as I keep telling my girlfriend.

A 10 minute search on Google revealed a couple of interesting tidbits:

Apparently, RadioShack had, at one point, sold a computer interface for this device, though given the manual on their website, I'm guessing it was 20 to 30 years ago.

Also, I saw references in other places that it's possible to get the Rolodex to transmit a single record. If you really want to decode it, what I would suggest is to set up to record the signature of the IR signal (Digital Storage Oscilloscope?), and have it send a known [short] entry. *(Maybe do so a few times in case it's using something that changes each transmission.)* Then change one letter in the known entry, and send it again.

With some patience, you should be able to break the code.

(I really doubt that they got very heroic about security on this gadget, especially as it's quite old.)

Of course, if you really want a challenge, you _could_ decode the LCD code. *(Remember that LCDs require a balanced signal, so go both positive and negative to the actual display.)*

Clark Jones
Gilbert, AZ

#4 I'm not familiar with this device, but I did a lot of similar stuff when this was probably built.

In the early days, the only real serial standard was RS-232 which used ±15V. These 'new pretenders' could not supply this, so many used 0-5V only. This just fell within the spec so that a standard port could talk to it (usually).

There's also the pain of getting handshaking right on adopters, etc. You don't have a real port to deal with, having tapped into the IR part, but it could help explain some of the difficulties.

Although there's no RS-232 port, data coming via IR may not be reliable without software handshaking (e.g., XON/XOFF with ASCII), but ASCII is not the only kid on the block. It could be EBSDIC or more likely as memory was always at a premium, encoded with reduced bits (think teletype close with shift-in and shift-out).

If you're determined to do it in hardware, bare the above in mind, and that most interfaces only like standard ASCII.

Or, try to tap the LCD feed? But, as the display is still just working, why not just re-key all the data — surely that would be quicker?

What a challenge! Good Luck!

Sally Jelfs
Brackley, UK

Good luck on that SB-301. It's a real beauty.

Bryan Bergeron

On the (Water) Level

The July 2016 Water Pump Protection System article by Joe Bidwell states on page 36: "I monitor the water level with a pressurized nylon tube that I taped to the pump before lowering it into the well."

I would like to know more about the water level monitor; how does it work, details about implementation, etc. Thanks!

Roy Emory
(With a 150 foot deep well
that has a low water level.)

I hope a picture (below) is worth a thousand words in this instance, since this system is a little hard to communicate in words. I don't know much physics, but do remember that a column of water develops pressure based on height. I used that principle in my system:

1 foot of water = 0.433 PSI
1 PSI = 2.31 feet of water

My own well is 500' deep and the water is usually

Pressure Gauge

Valve

Air Compressor

100 PSI 1/4" Plastic tubing

Ground Level

Measuring water level

Open valve to let air fill the tube down to the bottom of the well.

Close the valve and read the air pressure caused by the column of water.

Convert the pressure to feet of water by the ratio: 1 PSI = 2.31 Feet of water.

If you know the depth of the well, you can also determine how far the water is below the surface.

Bleed off the air before running the pump or air can get entrapped in the pump.

about 270' below ground, so I typically get about a 100# reading showing that I have about 230' of water in the well. Hope this is helpful!

Joe Bidwell

Nailed the Magnetos

In regards to the answer published in the July 2016 issue for question #6145, I feel it is slightly misleading. A "keeper" put across the poles of a "horseshoe" type permanent magnet will greatly reduce the slow weakening of the magnet by shunting much of its field from external disturbances.

I recently cleaned up two similar old telephone magnetos, whose magnets were pretty old and weak (hundred years? I don't know). I first tried quite a few turns of #22 wire on each pole (in series, wound in opposite directions on each pole), and turned 10 amps/12 VDC loose until the coils got a little too hot for me. The magnet now certainly picked up a longer chain of nails than before, but I thought a piece of steel like that perhaps could do better.

I wound different coils on each pole, #12 common THHN house wire, with as many turns as I could crowd on each pole (plus a few wraps of thin cardboard under the winding so it would slide on and off with a little urging). I connected my auto battery charger to the coils (in series again), and switched the charger to the 100 amp "start" position. A few five or 10 second pulses and the coils were almost too hot. THAT DID IT! The magnet would now pick up the whole box of nails. I was so proud!   A magneto overhaul facility had quoted $90 each to charge them on a professional magnet recharging machine.

Lynn W7LTQ since 1948
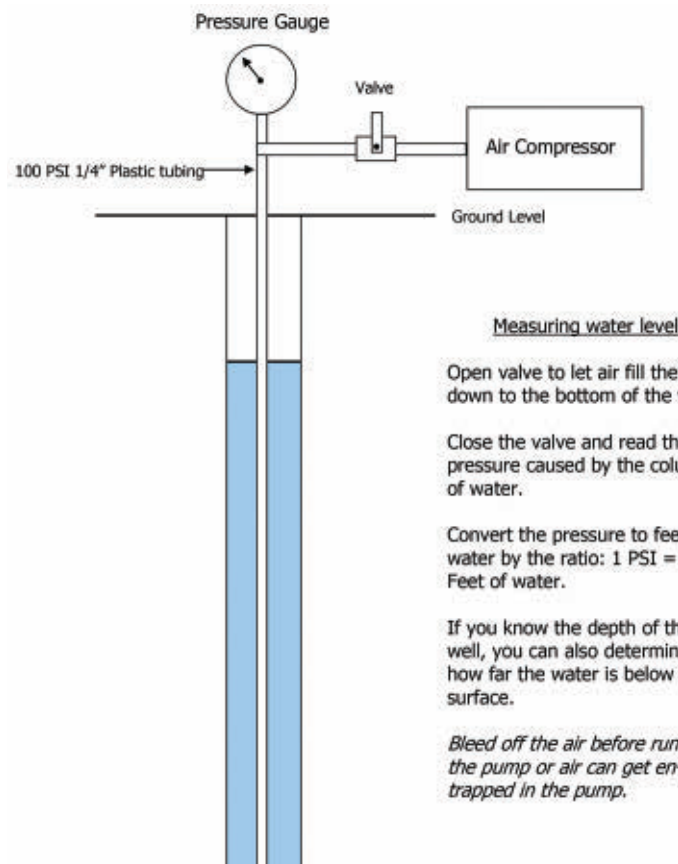
Need Know-How? Join the Service

In response to the question posed in a recent *Nuts & Volts* content newsletter on what advice would you give if asked how to get started in electronics, I would say join the Air Force or Navy in an electronic field of study. They will teach you basic electronics, then send you on to advanced training in your specialty. After you finish school — which will take longer than a year — you can serve the remainder of your time relatively safe compared to the Marines and Army. The Air Force does not typically send its most highly trained technicians into harms' way. I'm not saying that it can never happen, it is just unlikely.

Once you are out of the service, you can continue your education under the GI Bill, which is much better than the GI Bill I had when I served. If you like being in the Air Force or Navy, you can make a career out of it.

Joseph Massimino

ELECTRONET

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"Fetch newspaper, Rex!"

A giant, coffee-carrying IoT dinobot at the command of your index finger? Why not. In fact, wherever your imagination leads you, Anaren empowers you with the industry's easiest-to-use wireless connectivity platform. Scan the code to learn more and register for a chance to win a free *Atmosphere* MSDK.* Think. Build. Connect.

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